FORAMINIFERA FROM THE LATE PLEISTOCENE
(LATEST EEMIAN TO EARLIEST WEICHSELIAN)
SHELLY SANDS OF CAPE TOWN CITY CENTRE, SOUTH AFRICA

By

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(With 20 figures and 4 tables)

ABSTRACT

Samples from shelly sands exposed during deep trenching in Cape Town city centre have yielded diverse and relatively well-preserved foraminifera faunas. Fifty-three species are recognized, of which four are reworked from older deposits; none are new. The total assemblage is very similar to ones from off the mouth of the Orange River, substantially further north. From foraminiferal and geological considerations, a latest Pleistocene (latest Eemian to earliest Weichselian) age is proposed for the sequence, which is regarded as having acccumulated during the fall in sea-level at the end of the Eemian. The foraminifera lived in a wave-dominated, littoral environment, and the clean sands in which they occur are considered to be part of an extensive, regressive sheet sand that originally covered almost the entire continental shelf off all three coasts of South Africa, and which is still widely preserved. Similar shelly sands, also attributable to the latest Eemian–earliest Weichselian sea-level fall, occur in the coastal parts of both the 'Bredasdorp Formation' and the 'Alexandria Formation' (both termed Unit III), as well as along the Gamtoos coast (Unit III), at Durban (the Bluff Sandstone Formation), and extensively over the Zululand coastal plain (the Uloa Formation). Variable diagenesis has resulted in considerable cementing of these deposits at some localities. The foraminifera of the same sequence at several localities on the west coast are given in three appendices: for the Llandudno–Sandy Bay coast, Cape Peninsula, the Berg River mouth, and the Hoedjiespunt Peninsula, Saldanha.

CONTENTS

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INTRODUCTION

During deep trenching by the Municipality along several of Cape Town's city centre streets in late 1986, clean white, rather bleached, shelly quartz sands were exposed. These deposits appear to be confined to the more seawards parts of the city (Fig. 1). The sands are distinctly bedded, and undisturbed; human interference is confined to a distinct zone overlying the sands. Despite the clean and somewhat coarse nature of the sands, studied samples yielded a fairly well-preserved and diverse foraminifera fauna that contains a number of age-diagnostic species. The whole assemblage is almost identical to that described by McMillan (1987b) from the Late Pleistocene (latest Eemian to earliest Weichselian) deposits occurring on the inner Orange Shelf, just to the north of the Orange River mouth. A summarized stratigraphic column, based on observations by Mr V. H. Valicenti of SOEKOR (Pty) Ltd, Cape Town, at the time the trench was open, is given in Figure 2. The total thickness of the Cape Town sequence is not known. Two samples each were collected at the corner of Hertzog Boulevard and Oswald Pirow Street, and at the corner of Oswald Pirow and Martin Hammerschlagweg. Results of the foraminifera study are given in Table 1.

PREVIOUS WORK

Studies of Quaternary foraminifera in South Africa were initiated by Chapman (1907), who examined samples from a drill hole in the bed of the Buffalo River, East London. The precise age of the sequence, studied to a depth of 33,2 m below the bed of the river, is probably partly of Holocene, but mostly of latest Eemian–earliest Weichselian age. The latter age is indicated by the presence of *Elphidium crispum* (Linné) (given as *Polystomella crispa* by Chapman) through most of the studied sequence, suggesting that the Holocene is less than 4,57 m thick. Further comments on the use of *Elphidium crispum* as a zone fossil for the latest Eemian to earliest Weichselian deposits of South Africa are given below in the section on stratigraphy (see p. 129).

Most later work has involved lists of foraminifera species only, but Biesiot (1957) illustrated a number of the *in situ* foraminifera of the Uloa Formation at its type locality (see McMillan 1987a); these include the species of *Amphistegina*, *Elphidium*, and perhaps some of the miliolids, together with *Eponides zuluensis* Biesiot, *?Eponidella* sp. sensu Biesiot, *Rotalia beccarii* sensu Biesiot, *Cibicides lobatulus* (Walker & Jacob), and possibly *Nonion elongatum* sensu Biesiot.
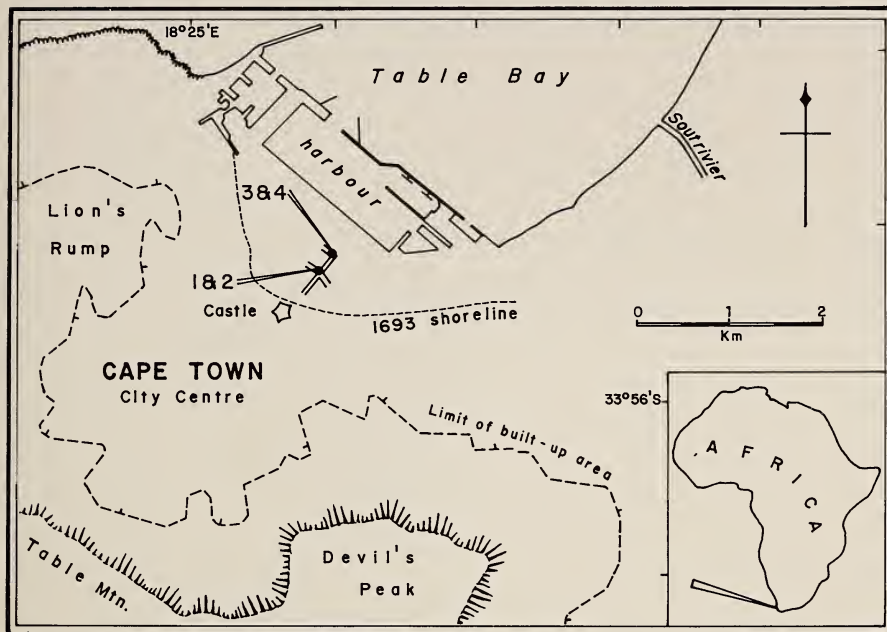
Fig. 1. Location of studied samples from the latest Eemian–earliest Weichselian regressive shelly sands (Unit III) beneath Cape Town city centre. Samples 1 and 2 are from the corner of Oswald Pirow Street and Hertzog Boulevard; 3 and 4 from the corner of Oswald Pirow Street and Martin Hammerschlagweg. Based on 1 : 50 000 topographic sheet 3318CD (Cape Town), 4th edition.
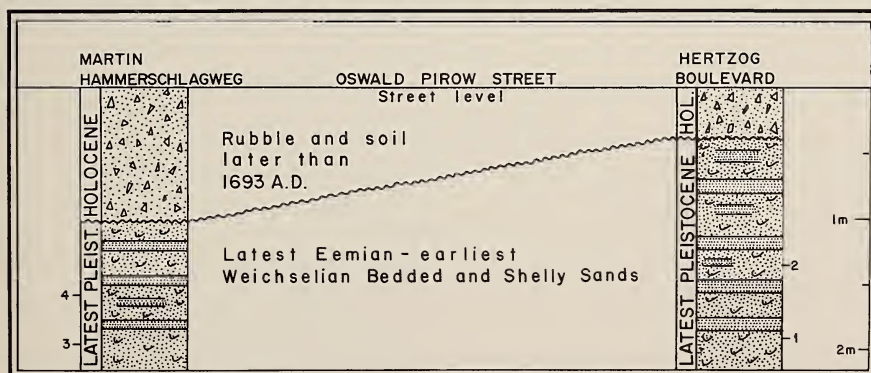

Fig. 2. The stratigraphy of exposures in deep trenches in Oswald Pirow Street, Cape Town city centre, as measured in November 1986, by Mr V. H. Valicenti, SOEKOR (Pty) Ltd. Sampled horizons are indicated (CTC 1 to 4).

TABLE 1

Distribution of foraminifera in studied samples from the latest Eemian–earliest Weichselian sands of Oswald Pirow Street, Cape Town city centre.

CTC-1	Sample number CTC-2	CTC-3	CTC-4	Sp. no.	Species
	1		1	1	*Spiroplectammina* sp.
		1	1	2	*Quinqueloculina contorta*
8	6	18	28	3	*Quinqueloculina dunkerquiana*
			2	4	*Quinqueloculina isabellei*
2			2	5	*Quinqueloculina* cf. *Q. lata*
1	1	1	5	6	*Quinqueloculina seminulum*
			11	7	*Quinqueloculina triangularis*
	1	2		8	*Quinqueloculina* cf. *Q. undulata*
4	6	24	34	9	*Quinqueloculina* spp. (broken)
		2	4	10	*Siphonaperta* sp.
2	1	2	3	11	*Miliolinella subrotunda*
		1		12	*?Dentalina* sp. (reworked)
		1		13	*Lagena semilineata* var.
			1	14	*Lenticulina* sp.
			1	15	*Oolina squamososulcata*
		1	3	16	*Oolina* sp. A
		1		17	*Fissurina lucida*
		1		18	*Fissurina* cf. *F. marginata*
		2		19	*Fissurina* spp. (reworked)
		1	1	20	*Guttulina* spp. (broken)
			1	21	*Bulimina marginata*
		1		22	*Uvigerina* sp. (reworked)
			1	23	*Trifarina angulosa*
		1		24	*Bolivina* sp.
		1		25	*Brizalina spathulata*
		16	8	26	*Cassidulina laevigata*
		1		27	*Cassidulina crassa* s.l.
		1		28	*?Gavelinopsis* sp. (reworked)
		1		29	*Planulinoides biconcavus*
		1	1	30	*Rosalina bradyi*
		1		31	*Rosalina* sp.
	2	22	10	32	*Glabratella australensis*
		3		33	*Cibicides fletcheri* s.l.
5	2	24	13	34	*Cibicides lobatulus*
		4	4	35	*Cibicides* spp. (reworked)
2	5	9	3	36	*Cibicidoides* sp.
		1		37	*Hyalinea balthica*
1	1	1		38	*Sphaerogypsina globulus*
	1			39	*?Acervulina* sp.
		14	3	40	*Elphidium advenum*
		6	1	41	*Elphidium* sp. A
		1	4	42	*Elphidum articulatum*
54	26	131	137	43	*Elphidium crispum* s.l.
	2	6	13	44	*Elphidium macellum* s.l.
		1		45	*Elphidium* sp. B
			1	46	*Astrononion echolsi*
		9	2	47	*Ammonia japonica*
1	1	3	6	48	*Ammonia parkinsonia* s.l.
11	16	105	146	49	*Pararotalia nipponica*
			1	50	indeterminate reworked rotalid
		1		51	*Globigerina (G.) bulloides*
		2		52	*Globorotalia (G.) inflata*
		4		53	*Neogloboquadrina* cf. *N. pachyderma*
91	72	429	452		Total number of tests

All the remaining fossils detailed by Biesiot (1957) are reworked from the Early and Middle Miocene (McMillan 1987*a*).

Lists of foraminifera from the coastal 'Bredasdorp Formation' and the coastal 'Alexandria Formation' were given by Rümke, in Spies *et al.* (1963) and Engelbrecht *et al.* (1962). Some of the samples described by Parr (1958), including those from the Bluff at Durban, are also of this age.

It is now certain that the *Pararotalia* cf. *P. inermis* (Terquem) emend. Le Calvez, and the *Ammonia beccarii* (Linné) var. 2 sensu McMillan (1974), from the Agulhas Bank, are also of latest Eemian–earliest Weichselian age. The former can now be referred to *Pararotalia nipponica* (Asano), whereas the latter are poorly preserved tests of the *Ammonia* sp. C (Alexandria) detailed by McMillan (1987*a*).

McMillan (1987*a*) illustrated *Ammonia* species from a variety of South African Pleistocene, Holocene and Pliocene localities as a preliminary attempt to correlate the many, geographically disparate deposits of these ages. McMillan (1987*b*) described in detail the stratigraphy and foraminiferal assemblages of the latest Eemian–earliest Weichselian and the Holocene silts and sands of the Orange Shelf, southern Namibia continental margin. Diagnostic zone foraminifera from the different aged rock units that comprise the 'Alexandria Formation' have been illustrated by McMillan (in press).

THE FORAMINIFERA ASSEMBLAGES

All four Cape Town samples yielded faunas dominated by the benthonic species *Elphidium crispum* (Linné) s.l. and *Pararotalia nipponica* (Asano). As is the case with all of the Pleistocene marine sand deposits preserved on the South African continental margin, planktonic foraminifera are rare. Species of the benthonic genera *Elphidium*, *Ammonia*, *Pararotalia* and *Cibicides* predominate, again in keeping with other Pleistocene marine sequences.

ENVIRONMENT OF DEPOSITION

A littoral, wave-influenced environment of deposition is indicated from both the foraminifera and the sediments. The clean nature of the sands, the abrasion and breakage of some foraminifera tests, and the presence of a number of foraminifera species that in life attach to a substrate, all clearly reflect a turbulent sea-floor, with highly oxygenated conditions both on the sea-bed and in the water column. A water depth of 10 m or less is suggested. The attached species include *Cibicides lobatulus* (Walker & Jacob), *Rosalina* sp., *Rosalina bradyi* (Cushman), *Glabratella australensis* (Heron-Allen & Earland) and *Sphaerogypsina globulus* (Reuss), and possibly *Cibicides fletcheri* Galloway & Wissler s.l. The macrofaunal remains in the sands, mainly bivalve and echinoid debris, are substantially comminuted.

It appears likely that the foraminifera tests, while evidently *in situ* in a stratigraphical sense, were much transported before coming to their final rest. It seems likely that these foraminifera lived in a sublittoral environment, possibly a kelp-bed, and were swept shorewards after death by wave action, to be incorporated into truly littoral deposits accumulating as the shoreline retreated. The retreat of the sea at this time would seem to have occurred over a fairly short interval (perhaps well within 5 000 years, if an analogy with the Holocene transgression holds good), so that the littoral sands laid down at any one locality may have soon no longer been subject to wave- and swell-induced abrasion, lying instead in coastal sand flats or dunes.

The presence of *Ammonia parkinsoniana* (d'Orbigny) s.l. in small numbers in the Cape Town samples suggests that the assemblage, if regarded as from one environment, derives from an area of slightly reduced salinity conditions. Thus, river output or other run-off affected the habitats of the studied foraminifera, but the lack of land-derived plant debris, seeds, charophyte oogonia and so on, together with the relatively small numbers of *Ammonia parkinsoniana*, clearly indicate the freshwater influence to have been an insubstantial one, perhaps as is the case in the Cape Town part of Table Bay at the present day. It seems that a comparison of numbers of *Ammonia japonica* (Hada), typical of shelf environments, with numbers of *Ammonia parkinsoniana*, characteristic of estuarine and littoral environments, may provide a simplified environmental indicator for these latest Pleistocene accumulations around the west and south coasts of South Africa.

Since most of the foraminifera species encountered in the Cape Town sands are known to live off the western Cape coast at the present day, it would appear that sea temperatures at the end of the Eemian were much the same as they are at present. However, until the full geographic ranges of the various species around the South African coast are better known, an improved understanding of water temperatures cannot be attempted.

STRATIGRAPHY AND CORRELATION

The foraminifera of the Cape Town sands show varying similarities to those of older Pleistocene deposits, those of deposits of the same age, and those of the Holocene. Generalized locations are given in Figure 3.

SYNCHRONOUS DEPOSITS OF THE SOUTH AFRICAN CONTINENTAL MARGIN

The Cape Town shelly sands can be correlated with ease to the sands and silts occurring to a considerable thickness (about 70 m according to Hoyt *et al.* 1969) off the mouth of the Orange River, based on the very close similarity of their foraminiferal faunas (see McMillan 1987*b*). Correlation is also possible with a number of deposits preserved about 8 m above high sea-level at the Hoedjiespunt Peninsula, Saldanha, along the Sandy Bay to Llandudno coastline, Cape
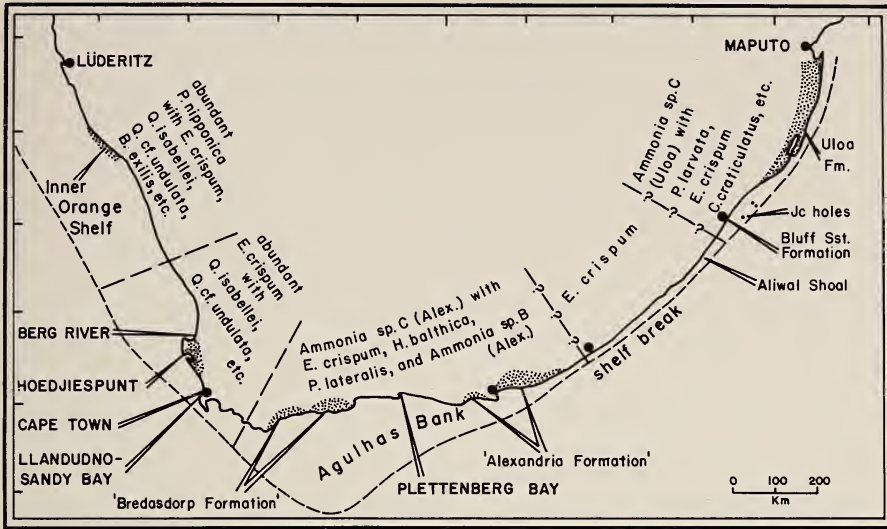
Fig. 3. Distribution of latest Eemian–earliest Weichselian deposits around the South African coast, of equivalent age to the shelly sands of Cape Town centre. The areas shown for the Varswater Formation, the 'Bredasdorp Formation', and the 'Alexandria Formation' are for the entire sequence, Unit I to Unit III. In all these areas Unit III occurs as a narrow strip along the present coast. The major foraminiferal facies, based mainly on *Ammonia* and *Elphidium* species are also shown. Species listed distinguish the Unit III sands from both older Pleistocene and Holocene deposits.

Peninsula, and below the level of the present Berg River mouth (see Appendices A, B, C).

Deposits of the same age also occur along the south coast of South Africa: the latest, most coastal portion of the 'Bredasdorp Formation' between Cape Agulhas and Mossel Bay, below the mouth of the Keurbooms and Bietou rivers at Plettenberg Bay and onshore adjacent to the estuary, and the latest, most coastal portion of the 'Alexandria Formation' between Port Elizabeth and Port Alfred, as well as the whole of the smaller area of 'Alexandria Formation' along the Gamtoos coast. Deposits of this age have been termed Unit III informally by the present author (see McMillan in press). It is now known that Unit III and Unit IV of the 'Alexandria Formation' are slightly different facies of the same rock sequence, and are of the same age (see McMillan in press). Unit III in the eastern Cape is characterized by polished foraminifera tests, with many normal marine shelf species, and the distinctive *Ammonia* sp. C (Alexandria) is common and widespread. Unit IV, seen only at Woody Cape, contains foraminifera assemblages dominated by miliolids, together with *Poroeponides lateralis* (Terquem), that derive from a more exclusively littoral environment.

Off the south coast, Unit III sediments are extensively preserved as a thin veneer over the majority of the Agulhas Bank. The sequence has been frequently

encountered in borehole tops as far offshore as the outermost shelf, down to a water depth of about 200 m. Foraminifera faunas remain uniform and distinctive throughout, and are easily correlated with those deposits occurring onshore at the present day. At borehole F–A 13, the latest Eemian–earliest Weichselian shelly deposits, together with the overlying Holocene interval (the two are separated by an unconformity), are no more than 0,5 m thick. *Ammonia* species from F–A 13 and E–B 1 have been previously discussed by McMillan (1987*a*). Where the latest Eemian–earliest Weichselian Unit III deposits unconformably overlie the shelly white limey clays of the Early Miocene (Burdigalian) over most of the middle and outer shelf on the Agulhas Bank, much reworking of the Miocene has occurred, so that the latest Pleistocene sediments are often white clays, with abundant Miocene foraminifera in some cases.

The thin sliver of coastal deposits preserved along the East London to Durban coast have only been examined for foraminifera by Parr (1958); the species listed by him from near Bats Cave, East London, are insufficient to determine what part of the Pleistocene (but presumably Unit III) is represented here. It seems certain now that most, possibly all, of the Bluff Sandstone Formation at Durban and the Uloa Formation, extensively developed over the Zululand coastal plain, are of the same age—latest Eemian to earliest Weichselian. Although very much thinner offshore, the sequence also occurs in the borehole tops of Jc–A 1, Jc–B 1 and Jc–C 1, where it lies unconformably between the Holocene and Middle or Early Miocene, and consists of a loose shelly sand. The eastern offshore sequence thus exactly duplicates that seen on the Agulhas Bank. Again, there is little change in the littoral, benthonic foraminifera of this unit, and *Ammonia* sp. C (Uloa) (possibly referable to *Challengerella persica* Billman, Hottinger & Oesterle), *Elphidium crispum* (Linné) s.l., *Planorbulinella larvata* (Parker & Jones) and *Cellanthus craticulatus* (Fichtel & Moll) have proved useful local indicators for Unit III from Durban northward.

Earlier comments on the age of the Uloa Formation have been made by McMillan (1987*a*), who suggested reasons for a probable middle Pleistocene age. However, the presence of *Elphidium crispum* s.l., together with feathered-suture *Ammonia*s in the east-coast and the south-coast sequences, as well as their unconsolidated nature on the outer shelf off both the east and south coasts, clearly argues for the two to be of the same age. Since the offshore deposits remain unconsolidated for the most part, it is clear that they have never been subjected to a major regression of the sea and the surf-zone, and must thus date from the last fall in sea-level at the end of the Eemian. It is clear from study of the Holocene sequences around South Africa that the early Holocene transgression, in strong contrast, was a very mild event in terms of its erosive power.

On the basis of the presence of *Elphidium crispum* (Linné), the Aliwal Shoal, south of Durban (Carter 1966; McCarthy 1967), would appear to be also of Unit III age.

In all of the above rock sequences, correlation of this youngest regressive event can be achieved in part by its contained littoral foraminifera, particularly the species of *Elphidium* and *Ammonia*, and partly by its stratigraphical relationships. Although, on following Unit III around the continental margin of South Africa, the foraminifera faunas change substantially, nevertheless with sufficient density of samples, key species can be traced until they overlap with other key species, and correlation is thus maintained. *Elphidium crispum* (Linné) s.l. has proved the most reliable species for identifying Unit III, though there are subtle differences in test morphology between east- and west-coast examples that remain to be defined. The major foraminiferal facies recognized in Unit III deposits so far, together with *local* age-diagnostic species, are shown in Figure 3.

McMillan (1987*a*) has proposed the use of different *Ammonia* species to identify the various latest Cainozoic (Pliocene, Pleistocene and Holocene) marine deposits of southernmost Africa. Subsequent unpublished work on the *Elphidium* species has indicated that they are morphologically more diverse and often more distinctive than the *Ammonia* species, and thus would seem to be a more useful group for correlation purposes. Perhaps in response to the changing environments available for occupation during high (glacial minima) and low (glacial maxima) sea-level stands by species of the two genera, it would seem that appearances of new species are more frequent than in the planktonic foraminifera (Globigerinacea) over the timespan of the Quaternary. Particularly in *Ammonia*, but also in *Elphidium*, the historical view has been that species of these genera show much morphological variation in their tests. On the contrary, intraspecific variation is as limited as in most other rotalid species, but the number of species in both genera is unusually large, and most appear to have survived for relatively short time periods, often markedly less than one million years in duration.

COMPARISON WITH OLDER PLEISTOCENE DEPOSITS

The regressive littoral sands of the end of the last interglacial can be identified as such in a number of ways. From a foraminiferal point of view, they contain the greatest number of species in common with extant littoral assemblages around South Africa. The foraminifera of the earlier Pleistocene and Pliocene deposits show a progressive decline in similarity with increasing age. A typical example of this is given by McMillan (in press) for the 'Alexandria Formation'. In both the oldest, Pliocene part of the 'Alexandria Formation', and the Pliocene of the Orange Shelf (McMillan 1987*b*), the benthonic foraminifera show no similarity with living South African species, though in deeper-water assemblages some conservative forms persist (e.g. *Pullenia*, *Gyroidina*).

Secondly, the latest Eemian–earliest Weichselian deposits can be recognized because they consist of unconsolidated or poorly cemented shelly sand, up to 86 m thick in the coastal 'Alexandria Formation', but often less than 1 m, that

covers most of the South African continental margin, though there are large areas where it is missing off the west coast. This sheet sand has suffered relatively little from later erosion. In contrast, relatively little now remains of the earlier Pleistocene regressive deposits, the remnants usually being unusually thick because of local, mild subsidence prior to deposition, and uplift after deposition has removed them from the erosive activities of subsequent regressions. Earlier Pleistocene deposits of this type are known from the west coast, especially in the vicinity of Saldanha and Langebaan, and in the older 'Bredasdorp Formation' and 'Alexandria Formation', inland from the present coast. It seems probable that the older, higher terraces (A to C) of the Oranjemund to Chameis Bay coast in southern Namibia should be included here, but foraminiferal study of them has not yet been attempted.

Thirdly, there is a tendency for the Unit III shoreline at maximum advance in the Eemian to be similar to the present shoreline, with the only major difference occurring on the Zululand coastal plain, which was entirely inundated during the Eemian. With the older Pleistocene and Pliocene deposits, a progressive divergence away from the present shoreline can be seen, which by Pliocene times was quite substantial, notably in the eastern Cape.

Off the south and west coasts of South Africa, the marine deposits of the latest Eemian to earliest Weichselian can be distinguished from older units by the particular presence of *Elphidium crispum* (Linné) s.l., as well as *Elphidium macellum* (Fichtel & Moll) s.l., *Ammonia japonica* (Hada), and *Ammonia parkinsoniana* (d'Orbigny) s.l. (see McMillan 1987a, 1987b). In addition, *Astrononion echolsi* Kennett, *Quinqueloculina isabellei* d'Orbigny, *Oolina* sp. A, *Elphidium* cf. *E. advenum* (Cushman) and *Cassidulina crassa* d'Orbigny s.l., as well as the very distinctive *Quinqueloculina* cf. *Q. undulata* d'Orbigny, are all unique to the latest Eemian to earliest Weichselian of the west coast (McMillan 1987b). Also characteristic of these youngest marine Pleistocene deposits is the widespread presence of mollusc shell retaining its life colours: purples, blues and pinks seem the most commonly preserved. In earlier Pleistocene deposits, all the mollusc shell is white.

Preliminary examination of the Varswater Formation (here regarded as later Early Pleistocene) at a number of localities, as well as the phosphatic lithofacies termed the 'Saldanha Formation' by Tankard (1975), has revealed the following foraminifera species: *Ammonia* sp. (similar to *Ammonia japonica*), *Elphidium* sp. (within the *Elphidium crispum–macellum* group), *Glabratella australensis* (Heron-Allen & Earland) locally in abundance, *Planulina* cf. *P. ariminensis* d'Orbigny and *?Gavelinopsis* sp. Most of these are unknown in the latest Eemian to earliest Weichselian of both the Orange Shelf (McMillan 1987b) and Cape Town city centre. The Pelletal Phosphorite Member of the Varswater Formation in phosphate exploration borehole Q12 from near the New Varswater Quarry, Langebaanweg, has yielded a somewhat different assemblage, with *Cibicides lobatulus* (Walker & Jacob), *Pararotalia nipponica* (Asano), *Elphidium advenum* (Cushman), *Pseudo-*

nonion cf. *P. chiliensis* (Cushman & Kellett), *Nonion boueanum* (d'Orbigny), *Trifarina angulosa* (Williamson), *Oolina* sp., *Elphidium* spp., *Rosalina* cf. *R. bradyi* (Cushman), *Planorbulina mediterranensis* d'Orbigny, *?Gavelinella* spp., *Cibicides* spp., *Ammonia* spp., *?Pseudononion* sp., and *Globigerina* cf. *G. bulloides* d'Orbigny. More work is necessary on these older Pleistocene deposits but, from the abundance of *Glabratella australensis* at many localities, a correlation of the Varswater Formation with Unit IIA of the 'Bredasdorp Formation' seems likely.

It must be emphasized that the majority of the foraminifera species employed in correlation of the southern African latest Cainozoic are of local value only. *Ammonia japonica*, *Ammonia parkinsoniana*, *Elphidium crispum* and *Elphidium macellum*, for example, range back to the Early Pleistocene or Pliocene in the Mediterranean or Japan. In the case of *Ammonia* and *Elphidium*, both were late arrivals to southern Africa. *Ammonia* is first seen in the Early Miocene of Mediterranean Europe, but in South Africa it first appears in the Early Pliocene. *Elphidium* is known from the Early Eocene (Loeblich & Tappan 1964), but first appears in South Africa in the Middle Miocene.

COMPARISON WITH HOLOCENE DEPOSITS

The bedded shelly sands exposed in the Cape Town municipal trenching lie seaward of the Holocene shoreline as it was in 1693, before the construction of the modern harbour works. The location, relative to the site of the Castle, is evident on old maps. There thus exists the possibility that the sands are Holocene in age, having accumulated prior to commencement of the land reclamation schemes associated with harbour development. However, a Holocene age can be discounted on a number of points.

The latest Pleistocene Unit III sands are rich in tests of *Elphidium crispum* (Linné) s.l., and this species is absent everywhere in the Holocene, except rarely where it has been reworked. Similarly, *Quinqueloculina* cf. *Q. undulata* d'Orbigny and the other species listed on page 139 are not known from the Holocene (see Fig. 4 for interpreted stratigraphic ranges). The absence of *Elphidium magellanicum* Heron-Allen & Earland, widespread in shallow marine environments off the west coast during the later Holocene (McMillan 1987b), also supports a pre-Holocene age. *Elphidium magellanicum* occurs in the present-day sands washed into the canalized mouth of the Soutrivier, just a little distance north-east of the study area. Finally, nearly all the tests from the trench sands are bleached and lack their life colours, whereas tests from Holocene samples include a high proportion that retain their natural golden-brown coloration. This is probably due to the destruction of the inner tectin lining of the test by bacteria and percolating groundwater.

Since the latest Eemian–earliest Weichselian sands are overlain by a mix of rubble and soil, the fate of any Holocene deposits at the site of the trenching, laid down prior to land reclamation, is unclear.

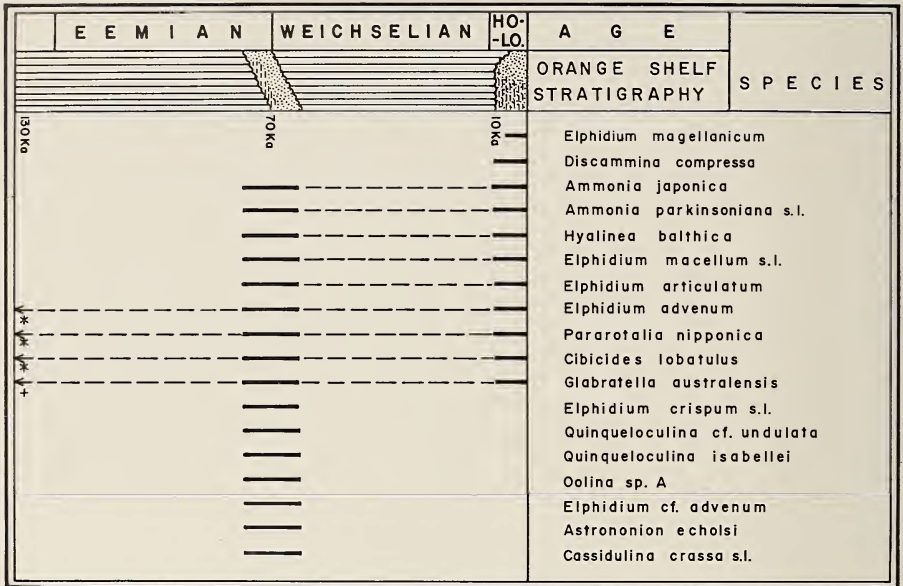| E E M I A N	W E I C H S E L I A N	HO- -LO.	A G E	
			ORANGE SHELF STRATIGRAPHY	S P E C I E S

Fig. 4. Range chart of selected time-restricted benthonic foraminifera species from the latest Quaternary littoral of the west Cape and Namibia coasts. Those species marked with an asterisk range back to near the Pliocene–Pleistocene boundary (base of Unit II) in the 'Alexandria Formation'; that marked by a cross ranges back in abundance to the later Early Pleistocene (base of Unit IIA) of the 'Bredasdorp Formation'.

REWORKING

A small number of the Cape Town tests are rather more poorly preserved than the majority, and are regarded as having been reworked. One, *?Gavelinopsis* sp., appears to be derived from the local equivalent of the Varswater Formation (later Early Pleistocene) sandy limestones, as it is creamy in colour and cemented; the same species occurs in the limestones at Saldanha. Occasional angular lumps of creamy sandy limestone present in the Cape Town sands are probably also from an equivalent of the Varswater Formation.

The remaining reworked tests may prove to be from the Early Miocene, though this cannot be confirmed from the species present, which are *?Dentalina* sp., *Cibicides* spp. and *Uvigerina* sp. (Fig. 9B). All show darker infillings to the chambers (and dark test calcite) than is typical for later Neogene or Quaternary foraminifera tests. An Early Miocene age seems most likely, because of the extensive development of very fossiliferous limy clays of this age that outcrop or subcrop below the Quaternary on the continental shelf off the west coast. Intensive reworking of Early and Middle Miocene foraminifera tests into latest Pleistocene regressive sands is known from the Orange Shelf (McMillan 1987b) and the Uloa Formation of Zululand (McMillan 1987a). The species listed above are not typical of the Varswater Formation.

PROCESSING METHODS

All of the samples studied, including those described in the three appendices, consist of clean or muddy, unconsolidated sands. These were easily washed with a cold-water spray over a 240 mesh/63 micron sieve. Those samples with substantial present-day plant debris were further cleaned by standing the washed residue in a beaker of water and picking off the floating debris using a pair of tweezers.

PHOTOGRAPHY AND DEPOSITION OF MATERIAL

Scanning electron microscope work was performed using the JEOL JSM240 microscope of the University College of Wales, Aberystwyth. The line drawings were executed with a camera lucida attachment to a light microscope.

All illustrated specimens were returned to their relevant assemblage slides; they can be distinguished by their gold coating. The eleven assemblage slides have been deposited with the Ph.D. thesis material of McMillan (1987b) in the foraminifera collections of the Department of Geology, University College of Wales, Aberystwyth. The slides possess the following McMillan collection numbers:

CTC–1:   Slide 118
CTC–2:   Slide 119
CTC–3:   Slide 120
CTC–4:   Slide 121
BR–1:   Slide 115
BR–2:   Slide 116
SB–1:   Slide 111
SB–LL1:   Slide 112
SB–LL2:   Slide 113
SB–LL3:   Slide 114
H–1:   Slide 117

A representative set of species slides has also been deposited in the Micro-palaeontology Unit of the South African Museum.

FORAMINIFERA TAXONOMY

The taxonomic scheme followed is essentially a combination of that of Loeblich & Tappan (1964, 1974), as revised by Haynes (1981). More detailed discussions and full descriptions of many of the species listed below can be found in McMillan (1987b).

Family **Textulariidae** Ehrenberg, 1838
Subfamily Spiroplectammininae Cushman, 1927
Genus *Spiroplectammina* Cushman, 1927

?Spiroplectammina sp.

Fig. 5A–B

Remarks

Two badly broken tests, which seem more likely to be referable to *Spiroplectammina* than *Textularia* from their test shape. The specimens differ from *Spiroplectammina atrata* (Cushman), prevalent in the Holocene deposits of the middle and outer Orange Shelf (McMillan 1987*b*), in being less compressed and with a more rounded test periphery. The latter feature, however, is poorly preserved. The grain size of the test wall is also coarser than either *Spiroplectammina atrata* from off the west coast or *Spiroplectammina wrightii* (Silvestri), known from the Holocene of the Agulhas Bank (McMillan 1974).

Family **Milliolidae** Ehrenberg, 1839
Subfamily Quinqueloculininae Cushman, 1917
Genus *Quinqueloculina* d'Orbigny, 1826

Quinqueloculina contorta d'Orbigny, 1846

Fig. 6A–C

Quinqueloculina contorta d'Orbigny, 1846: 298, pl. 20 (figs 4–6). McMillan, 1974: 33, pl. 2 (fig. 1a–c); 1987*b*: 164, pl. 2 (figs 8–11).

Remarks

Some variation in the degree of indentation of the rectangular test margins is evident in southern African individuals. Those from the Agulhas Bank (McMillan 1974) display strong indentations, but examples from the west coast are flatter (McMillan 1987*b*, present study) and more in keeping with the type illustrations of the species (D'Orbigny 1846). Some of the Orange Shelf tests display distinctly inflated margins, and the rectangular feature is almost lost (McMillan 1987*b*, pl. 2 (figs 8–9)). The toothplate of the Cape Town tests is perhaps a little more bladed and more elongate than that originally figured by D'Orbigny.

The species occurs in small numbers in the more nearly littoral intervals of the latest Eemian–earliest Weichselian of the Orange Shelf (McMillan 1987*b*), and over the middle and outer shelf on the Agulhas Bank in the Holocene (McMillan 1974). This discrepancy in environments between the latest Pleistocene and the Holocene is mirrored by several other species found in the Cape Town shelly sands.
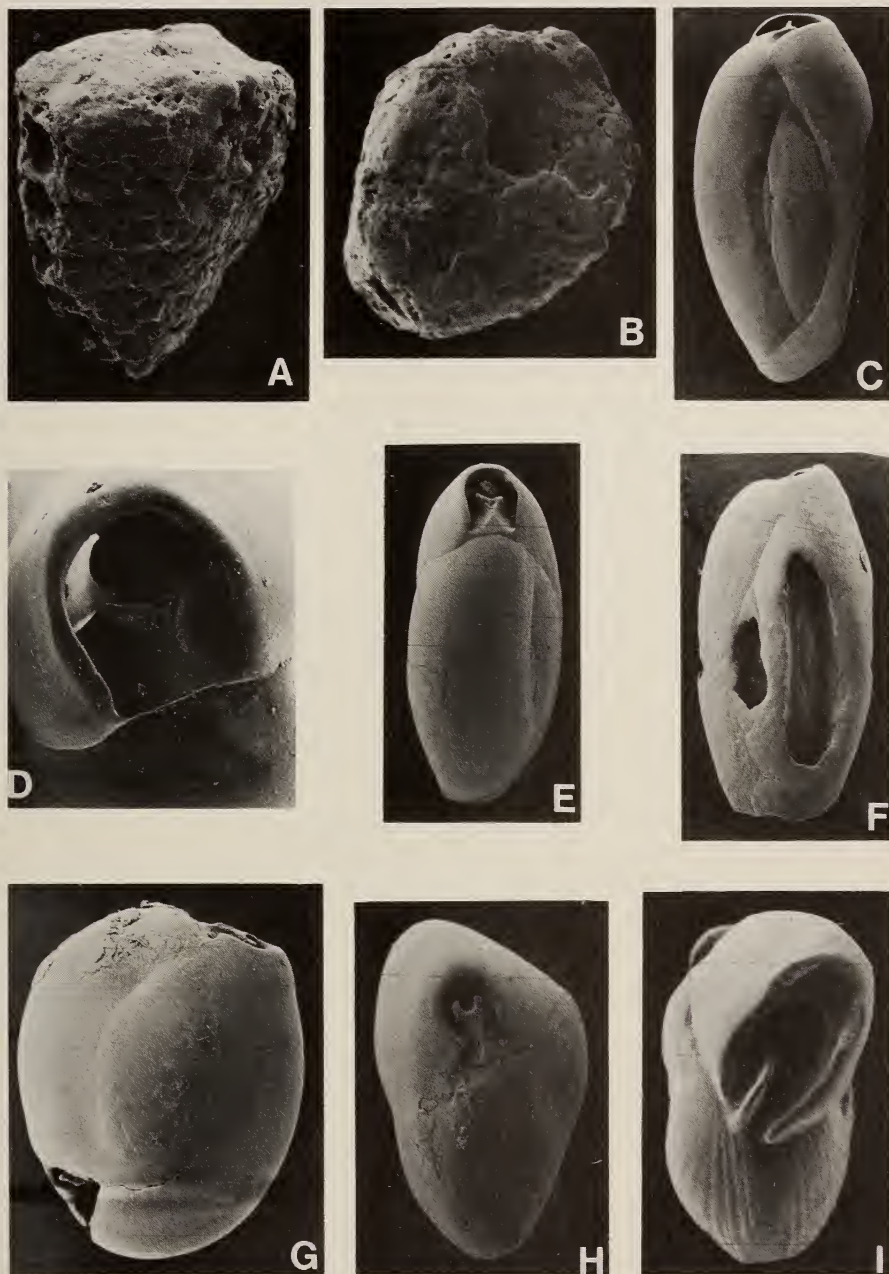
Fig. 5. A–B. *?Spiroplectammina* sp. A. Side view, CTC 4. × 130. B. Apertural view, same specimen. × 141. C–E. *Quinqueloculina isabellei* d'Orbigny. C. Side view, CTC 4. × 67. D. Apertural view, same specimen. × 520. E. Edge view, same specimen. × 60. F. *Quinqueloculina* cf. *Q. lata* Terquem. Side view, CTC 4. × 117. G–H. *Quinqueloculina triangularis* d'Orbigny. G. Side view, CTC 4. × 97. H. Apertural view, same specimen. × 113. I. *Quinqueloculina* cf. *Q. undulata* d'Orbigny. Apertural view, CTC 2. × 108.
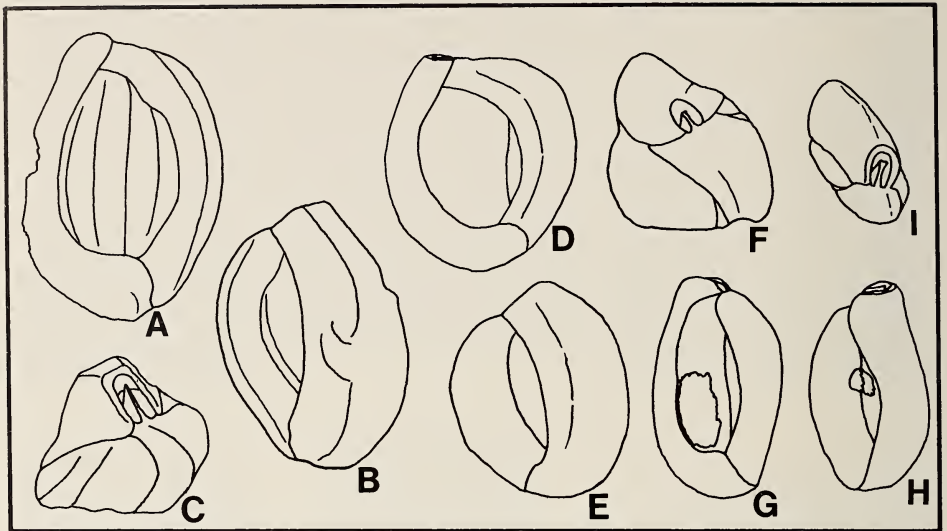
Fig. 6. A–C. *Quinqueloculina contorta* d'Orbigny. All same specimen, CTC 3. All × 67. A. Side. B. Opposing side. C. Apertural view. D–F. *Quinqueloculina dunkerquiana* (Heron-Allen & Earland). All same specimen, CTC 4. All × 67. D. Side. E. Opposing side. F. Apertural view. G–I. *Quinqueloculina seminulum* (Linné). All same specimen, CTC 3. All × 67. G. Side. H. Opposing side. I. Apertural view.

Quinqueloculina dunkerquiana (Heron-Allen & Earland, 1930)

Fig. 6D–F

Miliolina dunkerquiana Heron-Allen & Earland, 1930: 56, pl. 12 (figs 9–11).
Quinqueloculina dunkerquiana (Heron-Allen & Earland) Haynes, 1973*b*: 2, pl. 1 (fig. 8).
McMillan, 1987*b*: 166, pl. 2 (figs 12–13).
Quinqueloculina cf. *Q. dunkerquiana* (Heron-Allen & Earland) McMillan, 1974: 33, pl. 2 (fig. 1a–c).

Remarks

A number of small *Quinqueloculina* specimens with test width, height and outline, and chamber shape much in keeping with the north-west European shallow marine species *Quinqueloculina dunkerquiana*. As with the shell figured by Heron-Allen & Earland (1930) from present-day ·ediments of the Plymouth district, south-western England, the maximum height of tests is little greater than their maximum width. The distinctive indentations on the two last-formed chambers give a slightly sigmoiline appearance to the test if seen in apertural view, but the internal arrangement is always clearly quinqueloculine.

The species has been regarded as close to *Quinqueloculina seminulum* (Linné) by British authors (Heron-Allen & Earland 1930; Haynes 1973*a*, 1973*b*), but the gradation of forms recognized by Haynes (1973*b*, pl. 1) between the two species is far less evident in southern African late Quaternary assemblages. Specimens referable to *Quinqueloculina dunkerquiana* occur widely at the present

day in shallow marine, innermost shelf deposits around the entire South African coastline. The full stratigraphic range of the species remains unclear but on the Orange Shelf it extends throughout the latest Eemian to earliest Weichselian interval, while it is rare in the Holocene (McMillan 1987*b*).

Quinqueloculina isabellei d'Orbigny, 1839

Fig. 5C–E

Quinqueloculina isabellei d'Orbigny, 1839*b*: 74, pl. 4 (figs 17–19).
Quinqueloculina seminulum (*non* Linné) Boltovskoy *et al.*, 1980: 47, pl. 29 (figs 7–10, ?figs 11–13).
'*Quinqueloculina plataensis*' McMillan, 1987*b*: 169, pl. 3 (figs 1–4).

Remarks

The nearly circular aperture and strongly bifid apertural tooth, with the pronounced inflation of the final three chambers leading to a broad, evenly rounded test periphery, are distinctive features. These clearly distinguish the species from *Quinqueloculina seminulum* (Linné), with which it has been confused. *Quinqueloculina araucana*, also described by D'Orbigny (1839*b*) from present-day sediments off the west coast of South America, is clearly very similar to *Qinqueloculina isabellei*, and the two may be conspecific. The test outline of the type specimen of *Quinqueloculina isabellei* is strongly lobate, though this feature is not evident in the well-illustrated specimens of Boltovskoy *et al.* (1980), nor in the southern African tests here referred to D'Orbigny's species.

Boltovskoy *et al.* (1980: 47) considered their specimens to be part of a range of forms that they grouped under the name *Quinqueloculina seminulum*. If the neotype of *Quinqueloculina seminulum* from Rimini, Italy, illustrated by Loeblich & Tappan (1964, fig. 349 (no. la–c)), is regarded as typical for Linné's species, then the South Atlantic shells here referred to *Quinqueloculina isabellei* are clearly distinct. There is no gradation between *Quinqueloculina isabellei* and *Quinqueloculina seminulum* in either the Orange Shelf latest Eemian to earliest Weichselian shells (McMillan 1987*b*), or in those from Cape Town. See also remarks on *Quinqueloculina seminulum* (p. 138).

Quinqueloculina isabellei has yet to be found in the Holocene of southern Africa, whereas most, if not all, southern South American records are from the Holocene.

Quinqueloculina cf. *Q. lata* Terquem, 1876

Fig. 5F

see *Quinqueloculina lata* Terquem, 1876: 82, pl. 2 (fig. 8a–c). Mathieu *et al.*, 1971: 159, pl. 1 (figs 5–7).

Remarks

The few, rather damaged specimens from the Cape Town samples lack the embracing, quadrate nature of the final chambers of European littoral specimens

referred to *Quinqueloculina lata*. However, they are markedly more elongate than is typical for *Quinqueloculina seminulum* (Linné). In this respect they appear similar to the tests illustrated by Haynes (1973*a*, pl. 7 (figs 10, 12), 1973*b*, pl. 1 (fig. 1)) from Cardigan Bay, Wales, although the Cape Town tests lack such an elongate aperture.

Similar forms occur in the latest Pleistocene of the Orange Shelf (McMillan 1987*b*) to those in the Cape Town samples but, as with the majority of Pleistocene littoral miliolids, almost all are badly damaged and usually only the kernel of each test has preserved. An exact comparison of the Orange Shelf and Cape Town shells is thus not easy to achieve.

Quinqueloculina seminulum (Linné, 1758)

Fig. 6G–I

Serpula seminulum Linné, 1758: 786.
Quinqueloculina seminulum (Linné) Loeblich & Tappan, 1964: C458, fig. 349 (no. 1a–c).
    Haynes, 1973*a*: 74, pl. 7 (figs 14, 19), pl. 8 (fig. 3), pl. 32 (figs 1–3), text-fig. 18 (nos 1–4).
    McMillan, 1974: 35, pl. 2 (fig. 5a–c); 1987*b*: 172, pl. 3 (figs 5–6). Martin, 1981: 26, pl. 2 (fig. 11).

Remarks

The neotype illustrated by Loeblich & Tappan (1964), from the shore sands of Rimini, Italian Adriatic, has been relied on in establishing the identity of the various smooth-walled *Quinqueloculina* tests in the Cape Town samples. The neotype displays a rounded-triangular aperture with a rather short tooth that exhibits a distinctly bifid tip (apparently slightly broken on one side). In contrast, southern African tests reveal a more elongate-ovate aperture, within which lies a long, narrow tooth that extends for about three-quarters of the aperture length. The tooth is incipiently bifid at its free end, but this feature is never as well developed as the pronounced Y-shaped tooth of *Quinqueloculina isabellei* d'Orbigny. In keeping with the neotype, southern African tests of *Quinqueloculina seminulum* display a general test outline and chamber morphology sharply different to those seen in *Quinqueloculina isabellei*, notably in the sub-rounded, rather than broadly rounded test margin. However, the Cape Town tests are not as strongly triangular in cross-section as the Rimini neotype.

Quinqueloculina triangularis d'Orbigny, 1846

Fig. 5G–H

Quinqueloculina triangularis d'Orbigny, 1846: 288, pl. 18 (figs 7–9). Mathieu *et al.*, 1971: 159, pl. 1 (figs 8–10).

Remarks

In terms of its test morphology, this species compares closely with *Quinqueloculina dunkerquiana* (Heron-Allen & Earland), differing mainly in the possession of a distinctly bifid tooth, and lacking the indentations of the final two chambers. The Cape Town tests are a little more squat than those of Mathieu

et al. (1971), and more nearly as high as wide. The bifid tooth is particularly well developed in the figured specimen.

D'Orbigny (1946) described *Quinqueloculina triangularis* from the Miocene of the Vienna Basin; Mathieu *et al.* (1971) figured tests from the present-day beach sands of the Dunkerque coast, north France.

Quinqueloculina cf. *Q. undulata* d'Orbigny, 1852
Figs 5I, 7A

see *Quinqueloculina undulata* d'Orbigny, 1852: 195. Rosset-Moulinier, 1972: 140, pl. 6 (figs 5–7).
Quinqueloculina cf. *Q. undulata* d'Orbigny: McMillan, 1987*b*: 175, pl. 3 (figs 7–9).

Remarks

This distinctive species, with its finely grooved surface and very elongate aperture revealing a slender, tapering tooth, is at present known only from the latest Pleistocene (Unit III) off the west coast of southern Africa. D'Orbigny's (1852) species was partly distinguished by its undulating test margins, a feature that was also depicted, though not to so marked a degree, by Cushman (1945). Cushman's figured specimen is much less intensely ornamented than the original test of D'Orbigny (1852). The shells illustrated by Rosset-Moulinier (1972) are not undulate; she noted that the species was close to *Quinqueloculina bicornis* (Walker & Jacob), but more elongate in form.

None of the southern African tests, from Cape Town or the Orange Shelf, possess an undulate periphery, and they thus appear closest to those described by Rosset-Moulinier (1972) from the Brittany coast. D'Orbigny (1852) described the species from the Pliocene of Castel-Arquato and from present-day deposits near Rimini, both in Italy.

The illustrated test from Cape Town possesses a damaged apertural tooth; Orange Shelf tests display a bladed tooth, which extends for about three-quarters the length of the aperture (McMillan 1987*b*). The depressed area at either end of the aperture is also typical of the Orange Shelf examples.

Quinqueloculina spp.

Remarks

Many badly broken tests of smooth-walled, unornamented *Quinqueloculina* that probably mostly fall within the *Quinqueloculina seminulum–dunkerquiana* group.

Genus *Siphonaperta* Vella, 1957
Siphonaperta sp.
Fig. 7B–C

Quinqueloculina agglutinans (*non* d'Orbigny) Martin, 1974: 85; 1981: 25, pl. 2 (fig. 8).
Sigmoilopsis sp. McMillan, 1974: 37, pl. 2 (fig. 7a–c).
Sigmoilopsis schlumbergeri (*non* Silvestri) Martin, 1981: 27, pl. 2 (fig. 13).
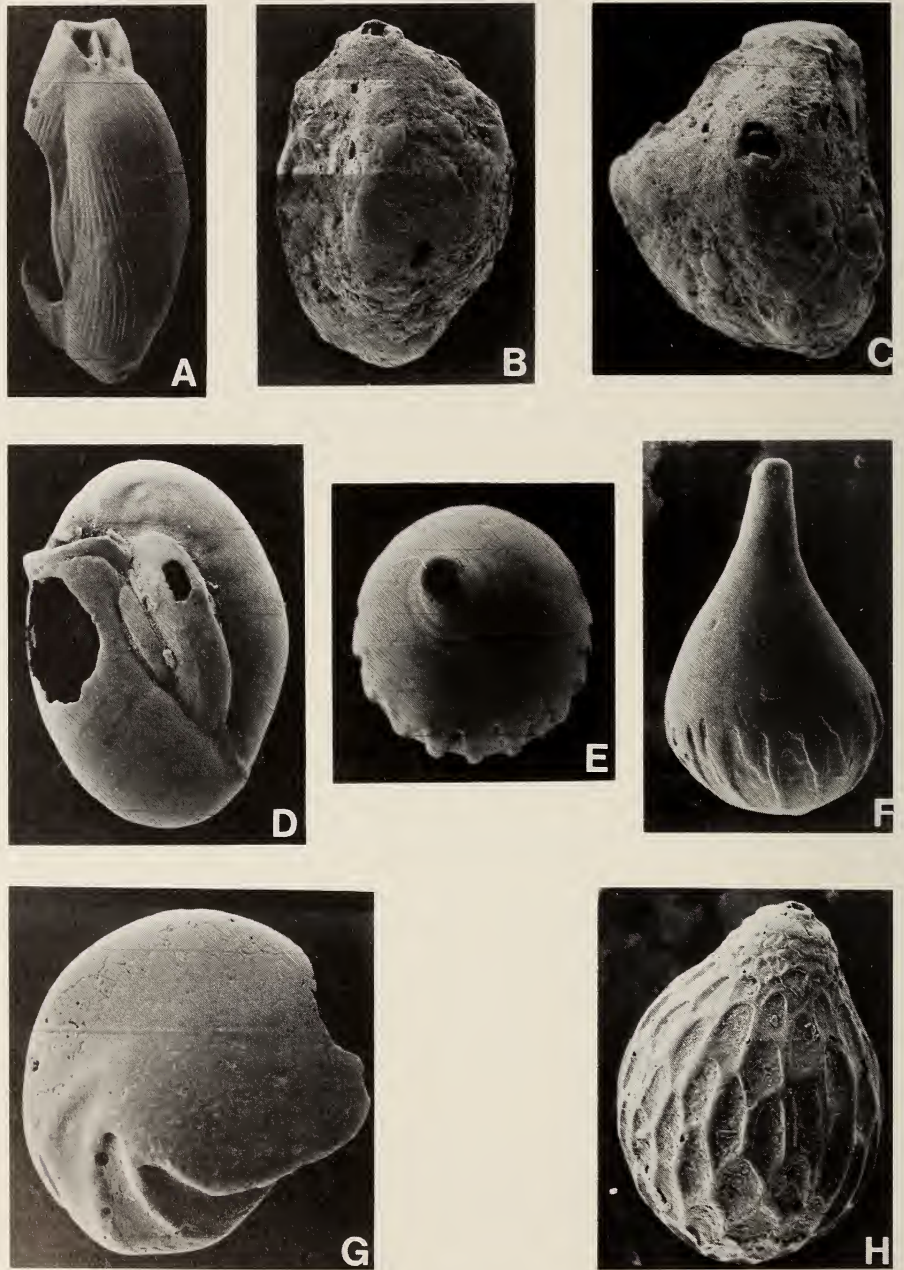*Quinqueloculina horrida* (*non* Cushman) Boltovskoy *et al.*, 1980: 46, pl. 27 (figs 17–20).

Fig. 7. A. *Quinqueloculina* cf. *Q. undulata* d'Orbigny. Oblique edge view, same specimen as Fig. 5I. × 65. B–C. *Siphonaperta* sp. B. Side view, CTC 4. × 96. C. Apertural view, same specimen. × 132. D. *Miliolinella subrotunda* (Montagu). Side view, CTC 4. × 110. E–F. *Lagena semilineata* Wright var. E. Apertural view, CTC 3. × 122. F. Side view, same specimen. × 112. G. *Lenticulina* sp. Side view, CTC 4. × 129. H. *Oolina* sp. A. Side view, CTC 4. × 168.

Remarks

The above, rather disparate references appear to be to the same species. The presence of an apertural neck and the rough, agglutinated test surface, as well as a quinqueloculine chamber arrangement, are indicative of the genus *Siphonaperta*, rather than *Quinqueloculina* or *Sigmoilopsis*. Sectioning of tests from the Orange Shelf Holocene (see McMillan 1987*b*, pl. 3 (fig. 11), text-fig. 2) shows the chamber arrangement to be quinqueloculine rather than sigmoiline.

These tests can be distinguished from *Quinqueloculina horrida*, described by Cushman (1947) from off Charleston, South Carolina, in being substantially more triangular in cross-section and somewhat more squat, and lacking the elongate neck and slender bifid apertural tooth of the United States species. *Quinqueloculina agglutinans*, in contrast, possesses subangular chamber margins, and a large, circular aperture with a phialine lip, but not developed on a neck (see Le Calvez & Le Calvez 1958: 166, pl. 9 (figs 103–104)).

Analysis of wall composition of one test dissolved in dilute hydrochloric acid (McMillan 1987*b*) revealed the presence of small lengths of broken sponge spicules in the wall, a feature that is not evident in external view. The species ranges throughout the latest Eemian to earliest Weichselian and Holocene sequences studied by McMillan (1987*b*), though it is substantially more abundant in the Holocene. The species does not occur in the older Pleistocene rocks of South Africa. Most of the Cape Town specimens are damaged, but the distinctive arrangement of coarse- and fine-grained quartz particles over the test wall easily distinguishes even badly fragmented tests.

Subfamily Miliolinellinae Vella, 1957
Genus *Miliolinella* Wiesner, 1931

Miliolinella subrotunda (Montagu, 1803)

Fig. 7D

Serpula subrotunda dorso elevato Walker & Boys, 1784: 2, pl. 1 (fig. 4).
Vermiculum subrotundum Montagu, 1803: 521.
Miliolinella subrotunda (Montagu) Haynes, 1973*a*: 56, pl. 5 (figs 5–6, 12–13), pl. 31 (figs 8–9), text-fig. 11 (nos 1–4), text-fig. 12 (nos 1–11). Ponder, 1974: 201, pl. 1 (figs 1–2), pl. 2 (figs 6–11).

Remarks

British researchers have considered the wide variety of forms encountered to be referable to one species: 'It would seem altogether inappropriate to separate some as *Miliolinella*, some as *Scutuloris* and to dispatch the irregular, wild-growing, hauerinid forms into a separate genus and even subfamily' (Haynes 1973*a*: 57). This concept is followed here. South African specimens also show much variation, from tight triloculine tests to ones that are loosely and irregularly triloculine, but the wild forms are by and large missing from the cool waters of the west coast.

Miliolinella subrotunda occurs widely in the South African littoral at the present day, from cold-water west coast to warm-water east coast. The species ranges back to the latest Eemian to earliest Weichselian on the Orange Shelf (McMillan 1987*b*), but its earlier record in southern Africa is as yet unclear.

Family **Nodosariidae** Ehrenberg, 1838

Genus *Lagena* Walker & Jacob, 1798

Lagena semilineata Wright, 1886 var.

Fig. 7E–F

see *Lagena semilineata* Wright, 1886: 320, pl. 26 (fig. 7).
Lagena semilineata (*non* Wright) Earland, 1934: 161, pl. 7 (figs 19–20).
Lagena semilineata Wright var. McMillan, 1987*b*: 204, pl. 5 (figs 9–11).

Remarks

The single specimen is not particularly well formed, and the ornamentation is not quite typical of the tests described by McMillan (1987*b*) from the Orange Shelf. The group of short apical spines of this specimen are poorly developed, lost perhaps through abrasion of the test. The flat-topped, tapering ribs that occupy much of the lower half of the globular part of the test are rather more irregularly formed, particularly in their varying width and length, than is usual. There also are occasional tubercular or rugose developments in the depressed areas between the ribs. However, the style of the ornamentation is so distinctive that there can be no doubt that the Cape Town specimen and those from the Orange Shelf are the same variety.

Genus *Lenticulina* Lamarck, 1804

Lenticulina sp.

Fig. 7G

Remarks

One broken specimen that appears to be *in situ*, may be referable to one of the rather conservative, unornamented species typified by *Lenticulina gibba* (d'Orbigny). Little can be made of the single specimen.

Family **Glandulinidae** Reuss, 1860

Subfamily Oolininae Loeblich & Tappan, 1961

Genus *Oolina* d'Orbigny, 1839

Oolina sp. A McMillan, 1987

Figs 7H, 8A–B

Oolina sp. A McMillan, 1987*b*: 220, pl. 6 (figs 13–14).

Remarks

This graceful, pyriform *Oolina* occurs rarely in the sandier, littoral deposits of the latest Eemian to earliest Weichselian of the Orange Shelf (McMillan
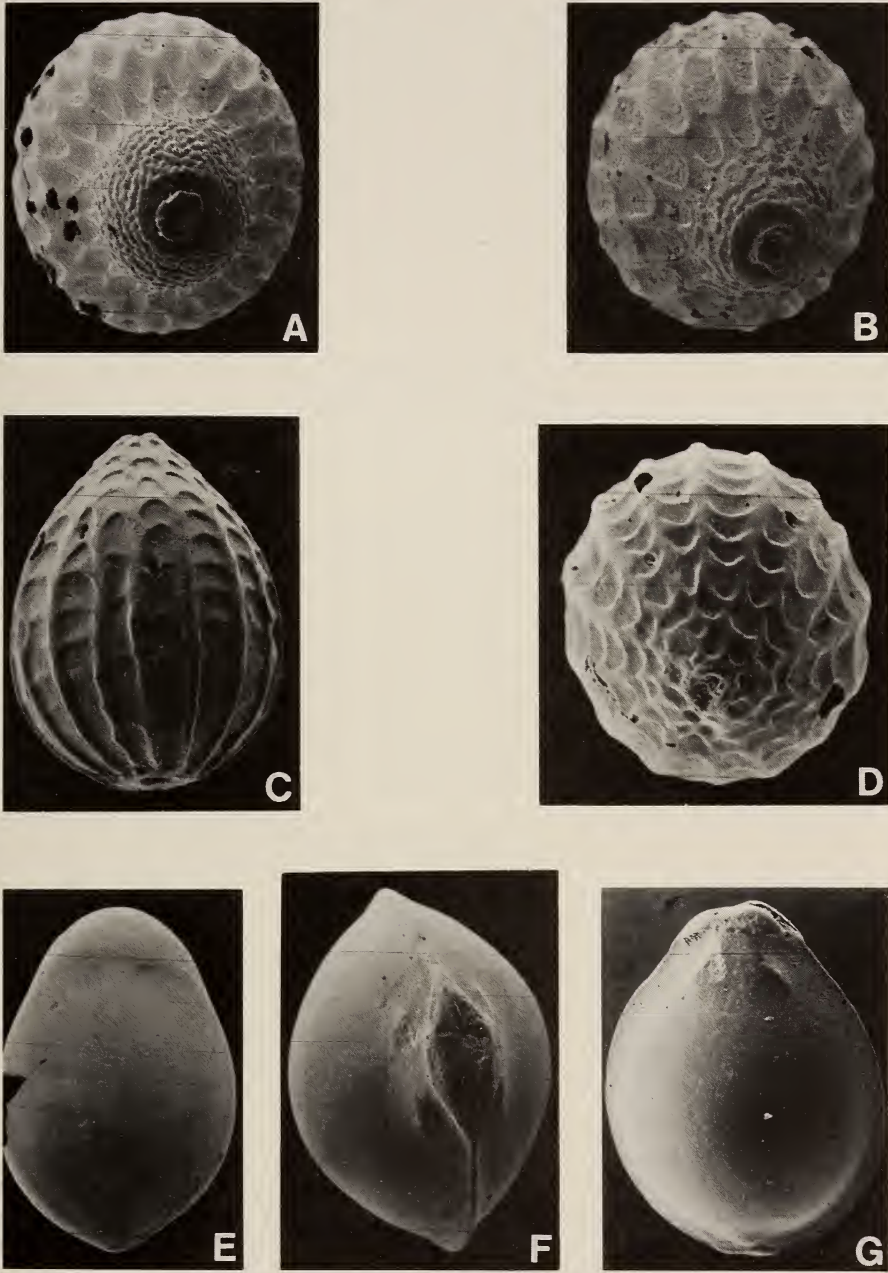
Fig. 8. A–B. *Oolina* sp. A. A. Apertural view, CTC 4. × 156. B. Apertural view, same specimen as Figure 7H. × 173. C–D. *Oolina squamososulcata* (Heron-Allen & Earland). C. Side view, CTC 4. × 206. D. Apertural view, same specimen. × 246. E. *Fissurina lucida* (Williamson). Side view, CTC 3. × 327. F–G. *Fissurina* cf. *F. marginata* (Walker & Boys). F. Apertural view, CTC 3. × 204 G. Side view, same specimen. × 161.

1987*b*). The species is distinguished by a vertically elongated hexagonal ribbing pattern ornamenting the test surface. Some variation is evident in the height of the elongated hexagons at the maximum width of the test; those from Cape Town exhibit more nearly regular hexagons than those from further north.

The narrower part of the test adjacent to the aperture is marked with small depressions and protrusions that give the surface a rather scaly, reptilian appearance. The subcircular aperture is developed on a short neck, which in well-preserved examples is almost phialine and ornamented with many short, vertically aligned grooves.

Oolina squamososulcata (Heron-Allen & Earland, 1922)
Fig. 8C–D

Lagena squamoso-sulcata Heron-Allen & Earland, 1922: 151, pl. 5 (figs 15, 19).
Oolina squamoso-sulcata (Heron-Allen & Earland) Loeblich & Tappan, 1953: 74, pl. 12 (figs 6–7).

Remarks

The single test compares closely with *Oolina squamososulcata* except that the horizontally aligned ribs ornamenting the test are more arched, and they fade away only slowly toward the apical end of the test, rather than disappearing abruptly about midway down. The holotype figured by Heron-Allen & Earland (1922) displays 13 vertical ribs; Loeblich & Tappan (1953) reported that their tests exhibit about 12 to 20; the present example possesses 15.

Genus *Fissurina* Reuss, 1850
Fissurina lucida (Williamson, 1848)
Fig. 8E

Entosolenia marginata (Montagu) var. *lucida* Williamson, 1848: 17, pl. 2 (fig. 17).
Fissurina lucida (Williamson) Murray, 1971: 97, pl. 39 (figs 1–3). Boltovskoy *et al.*, 1980: 32, pl. 15 (figs 17–20).

Remarks

One specimen, rather damaged, but closely comparable to Orange Shelf examples of this species. As with *Fissurina marginata* (Walker & Boys), it would seem to be confined to cool, shallow marine environments, off the west coast of southern Africa only, in both the latest Pleistocene and the Holocene (McMillan 1987*b*).

Fissurina cf. *F. marginata* (Walker & Boys, 1784)
Fig. 8F–G

see *Serpula (Lagena) marginata* Walker & Boys, 1784: 2, table 1, fig. 7.
see *Fissurina marginata* (Walker & Boys) Feyling-Hanssen, 1964: 315, pl. 15 (fig. 22). Haynes, 1973*a*: 97, fig. 20 (nos 7–8). McMillan, 1987*b*: 225, pl. 7 (figs 2–3).

Remarks

This single example displays several slight differences from the tests seen in the latest Pleistocene and Holocene of the Orange Shelf (McMillan 1987*b*). The

peripheral ornamentation is more nearly carinate rather than a rounded thickening; the lips on each side of the slit aperture are thicker but less elongate; and there are two raised areas on each side of the test, a little below the aperture. The raised features are low elongate protrusions, aligned roughly parallel to the test periphery. The degree of inflation and the general outline of the Cape Town test is about the same as seen in the Orange Shelf specimens.

A rounded peripheral ornamentation would seem to be closer to *Fissurina marginata* in British waters (Haynes 1973a: 98), so that this Cape Town example rather falls outside the confines of the north-west European interpretation of the species.

<div align="center">

Family **Buliminidae** Jones, 1875

Genus *Bulimina* d'Orbigny, 1826

Bulimina marginata d'Orbigny, 1826

Fig. 9A

</div>

Bulimina marginata d'Orbigny, 1826: 269, pl. 12 (figs 10–12). Murray, 1971: 119, pl. 49
    (figs 1–7). Knudsen, 1973: 181, pl. 2 (figs 10–11). Martin, 1981: 41, pl. 4 (figs 8–9).

Remarks

One specimen, showing rather poorly incised steps into the bases of the later chambers, but with a distinct fringe of blunt spines near the lower margins of some chambers. The test is abraded and has been subject to boring, but is clearly comparable to the more distinctive tests detailed by Martin (1981) and McMillan (1987b) from further north. *Bulimina marginata* ranges throughout the latest Eemian–earliest Weichselian and the Holocene sequences of the Orange Shelf (McMillan 1987b).

<div align="center">

Family **Uvigerinidae** Haeckel, 1894

Genus *Trifarina* Cushman, 1923

Trifarina angulosa (Williamson, 1858)

Fig. 10A–B

</div>

Uvigerina angulosa Williamson, 1858: 67, pl. 5 (fig. 140).
Trifarina angulosa (Williamson) Knudsen, 1971: 241, pl. 18 (figs 8–9). Haynes, 1973a: 126,
    pl. 10 (figs 12–13, 16–17), pl. 11 (fig. 11).

Remarks

One example, with the terminal part rather broken. However, it clearly shows the triserial chamber arrangement, the tricarinate test periphery, the nearly triangular cross-section to the test, and irregular, vertically aligned ribs on the test surface. The species occurs throughout the latest Eemian to earliest Weichselian and the Holocene of the Orange Shelf (McMillan 1987b), where it shows a considerable range in its surface ornamentation of vertically aligned ribs. Tests range from being almost smooth, with only the three peripheral keels, to densely
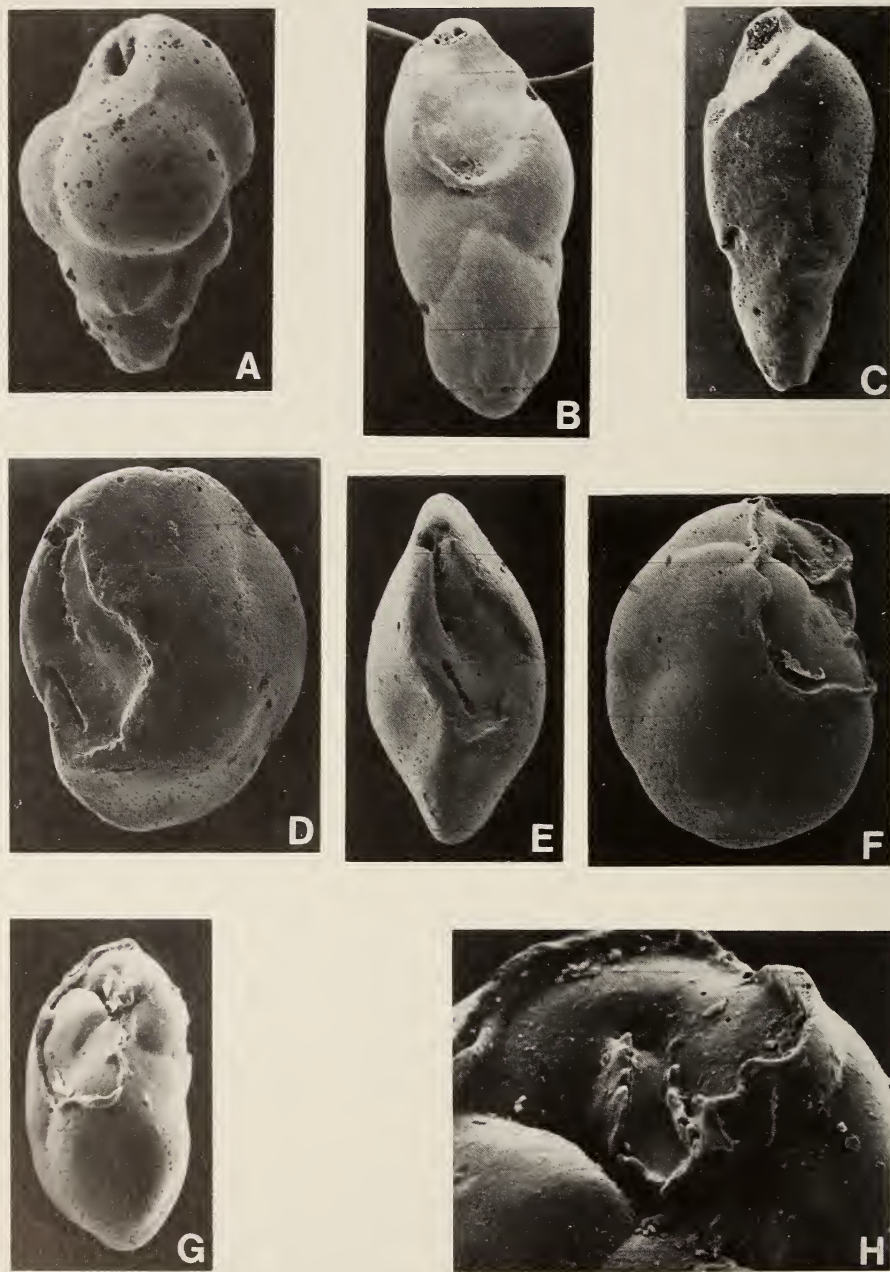
Fig. 9. A. *Bulimina marginata* d'Orbigny. Side view, CTC 4. × 123. B. *Uvigerina* sp. (reworked). Side view, CTC 3. × 133. C. *Brizalina spathulata* (Williamson). Side view, CTC 3. × 153. D–E. *Cassidulina laevigata* d'Orbigny. D. Side view, CTC 4. × 136. E. Apertural view, same specimen. × 129. F–H. *Cassidulina crassa* d'Orbigny s.l. F. Side view, CTC 3. × 187. G. Apertural view, same specimen. × 177. H. Close up of foramen, showing serrate margins, same specimen. × 646.
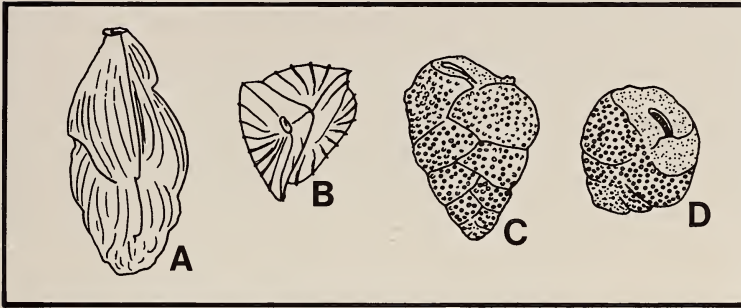
Fig. 10. A–B. *Trifarina angulosa* (Williamson), same specimen, CTC 4. Both × 67. A. Side view. B. Apertural view. C–D. *Bolivina* sp., same specimen, CTC 3. Both × 135. C. Side view. D. Apertural view.

ribbed over almost the entire exterior. Variation also occurs in the intensity of the ribs, some shells displaying few strongly developed ones, whereas others reveal many closely spaced fine ribs.

Family **Bolivinitidae** Cushman, 1927

Genus *Bolivina* d'Orbigny, 1839

Bolivina sp.

Fig. 10C–D

Remarks

One small test, ornamented with fine, dense pitting over the surface. The specimen shows some resemblance to *Bolivina variabilis* (Williamson), but is too juvenile a shell to make a reliable identification.

Genus *Brizalina* Costa, 1856

Brizalina spathulata (Williamson, 1858)

Fig. 9C

Textularia variabilis Williamson var. *spathulata* Williamson, 1858: 76, pl. 6 (figs 164–165).
Brizalina spathulata (Williamson) Hedley *et al.*, 1965: 21, pl. 6 (fig. 23a–b), text-fig. 6A–G.
    Haynes, 1973a: 135, fig. 25 (nos 10–13).

Remarks

One example, rather damaged. A narrow test when compared to examples from off the Orange River, but the arrangement and coarseness of the test perforations, the sub-rounded acute margin to the test, and the angle at which the sutures decline to the margin are closely comparable. The central zig-zag suture of the Cape Town test is particularly limbate and prominent.

Brizalina spathulata ranges throughout the latest Eemian and earliest Weichselian, and the Holocene of the Orange Shelf (McMillan 1987b). However,

in the latest Pleistocene, the species is widespread through the sandier, more nearly littoral parts of the sequence; these tests lack any substantial carination of the periphery (see McMillan 1987*b*, pl. 11 (figs 10–11)). The shell from the Cape Town samples is of this type. In contrast, in the Holocene, the species appears commonest in more offshore, shelf environments; these tests usually possess a rather bladed carina (see Martin 1981, pl. 3 (figs 12–13); McMillan 1987*b*, pl. 11 (fig. 12)). There is thus the possibility that two varieties are represented off the west coast in the Late Quaternary.

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Family **Cassidulinidae** d'Orbigny, 1839

Genus *Cassidulina* d'Orbigny, 1826

Cassidulina laevigata d'Orbigny, 1826

Fig. 9D–E

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Cassidulina laevigata d'Orbigny, 1826: 282, pl. 15 (figs 4–5). Knudsen, 1971: 246, pl. 7 (figs 20–21), pl. 18 (fig. 12). Boltovskoy *et al.*, 1980: 22, pl. 7 (figs 4–6).

Remarks

Few specimens, all distinguished from the similar species *Cassidulina carinata* Silvestri by a rounded, non-carinate margin, coarser test perforations and thicker walled test. The precise relationship between the two species is not clear. On the Orange Shelf, *Cassidulina laevigata* occurs in abundance in the littoral and sublittoral deposits of the latest Eemian–earliest Weichselian, but is present only rarely in the nearshore Holocene. *Cassidulina carinata*, in contrast, is rare in the latest Pleistocene, but common in the offshore (middle to outer shelf) Holocene. It remains possible that the two species are two facies-controlled *formae* of one species.

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Cassidulina crassa d'Orbigny, 1839 s.l.

Fig. 9F–H

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see *Cassidulina crassa* d'Orbigny, 1839*b*: 56, pl. 7 (figs 18–20).
Cassidulina crassa d'Orbigny 'intermediate form' Heron-Allen & Earland, 1932: 358.
Cassidulina crassa d'Orbigny forma *media* Lena, 1966: 316, pl. 2 (fig. 7).

Remarks

One test, which like those present in the latest Pleistocene of the Orange Shelf, is not *Cassidulina crassa* sensu stricto but a smaller form, first recognized by Heron-Allen & Earland (1932) from the seas around the Falkland Islands. This form, termed 'intermediate', was believed by Heron-Allen & Earland to be a juvenile or pauperate stage of *Cassidulina crassa*, as first described by D'Orbigny (1839*b*).

Tests possess a rather short aperture, extending from the interio-marginal suture, up toward, but not reaching, the test periphery. There is no extension of the aperture along the interio-marginal suture, as is seen in *Cassidulina crassa*

'small type' of Heron-Allen & Earland (1932, pl. 9 (figs 29–31)). Some subsequent listings of the 'intermediate form' have been made by Boltovskoy (1959, 1961) and Lena (1966) from the coast of Argentina.

Cassidulina crassa s.s. would seem to be absent in southern African waters, both in the Pleistocene and the Holocene. The 'intermediate form' appears to be confined to deposits of the latest Eemian–earliest Weichselian, and to the cold waters off the west coast.

Family **Discorbidae** Ehrenberg, 1838
Genus *Planulinoides* Parr, 1941

Planulinoides biconcavus (Jones & Parker, 1862)

Fig. 11A–C

Discorbina bi-concava Jones & Parker, *in* Carpenter, 1862: 201, fig. 32G.
Discorbina biconcava Parker & Jones (*sic*) Parker & Jones, 1865: 385, 422, pl. 19 (fig. 10a–c).
    Brady, 1884: 653, pl. 91 (fig. 2a–c).
Planulinoides biconcavus (Jones & Parker) Parr, 1941: 305, fig. a–c. Loeblich & Tappan, 1964:
    C584, fig. 458 (nos 4a–c, 5–6). Lowry, 1987: 269, pl. 17 (fig. 1a, c, ?1b).
Planulinoides biconcava (Jones & Parker) (*sic*) McMillan, 1974: 58, pl. 5 (fig. 5a–c).
Discorbinella biconcava (Jones & Parker) Carter, 1978: 19, pl. 1 (figs 2–3).

Remarks

This very distinctive species, widespread in shallow marine environments around south-east Australia at the present day (Carpenter 1862; Parker & Jones 1865; Brady 1884; Chapman 1909; Parr 1941, 1945; Collins 1974), also occurs sporadically around southernmost Africa. Specimens from the middle shelf of the Agulhas Bank (McMillan 1974) are always abraded and scoured, and clean tests would seem to be lacking. Whether this indicates that *Planulinoides biconcavus* is restricted to latest Pleistocene (latest Eemian–earliest Weichselian), Unit III deposits on the Agulhas Bank, rather than the Holocene as well, and has been reworked into the Holocene, is not fully clear at present.
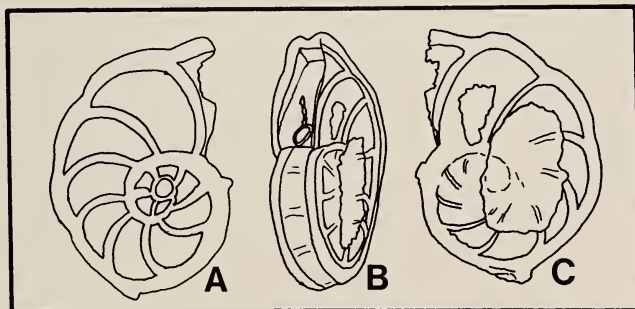

Fig. 11. *Planulinoides biconcavus* (Jones & Parker). All same specimen, CTC 3. All × 68.
A. Dorsal view. B. Apertural view. C. Ventral view.

Planulinoides biconcavus occurs in small numbers on the Agulhas Bank (McMillan 1974; Lowry 1987), and Lowry recorded it between 107 m and 890 m water depth. The species appears to be absent off the west coast in the Holocene and Pleistocene, except for the single specimen from the present study. However, in the Early Miocene of the Orange Shelf, a similar, perhaps identical species occurs (McMillan 1975). A full comparison of the Miocene and Late Quaternary specimens has not yet been attempted. In Australia, the species is known from the Early Miocene (Heron-Allen & Earland 1924), the Middle Miocene (Mitchellian) (Carter 1978), and the Early and Middle Pliocene (Cheltenhamian and Kalimnan) (Parr 1939, 1941) of Victoria.

The Cape Town test is typical in its shell morphology, but as is often the case with the Agulhas Bank specimens examined by McMillan (1974), the thinner-walled, less-ornamented ventral side, with the small rounded flaps over the spiral suture, is very badly broken. The elongate-ovate, oblique primary aperture is distinct, though rather damaged. Despite showing some morphological similarities to *Planulina ariminensis* d'Orbigny, even very badly broken tests of *Planulinoides biconcavus* are easily distinguished, since they entirely lack the coarse test perforations of D'Orbigny's species.

Some differences in size of the flaps on the ventral side, over the spiral suture, can be seen. Tests such as that illustrated by Carter (1978) display large triangular flaps, whereas southern African Quaternary examples reveal only small, rounded flaps.

Genus *Rosalina* d'Orbigny, 1826

Rosalina bradyi (Cushman, 1915)

Fig. 12A–C

Discorbina globularis (*non* d'Orbigny) Brady, 1884: 643, pl. 86 (fig. 8a–c).
Discorbis globularis (d'Orbigny) var. *bradyi* Cushman, 1915: 12, pl. 8 (fig. 1a–c).
Rosalina bradyi (Cushman) Hedley *et al.*, 1967: 42, pl. 1 (fig. 3), pl. 11 (fig. 2a–c), text-figs 50–55.

Remarks

This essentially Indo-Pacific species appears to reside preferentially in patches of *Corallina* alga in the littoral (Hedley *et al.* 1967). It occurs in association with *Corallina* debris in vibracore 620/40 on the nearshore Orange Shelf, in sandy sediments of earliest Weichselian age (McMillan 1987b). The illustrated test from Cape Town is closely comparable to those from the Orange Shelf, although, being a rather juvenile shell, the limbation of the dorsal sutures is not well developed. The 'milled edge' of *Rosalina bradyi* (Cushman, 1915) is caused by the peripheral coarse perforations when viewed from the ventral side, which are visible at right angles through the glassy shell. This feature, obviously, is obscured in the scanning electron microscope photographs.

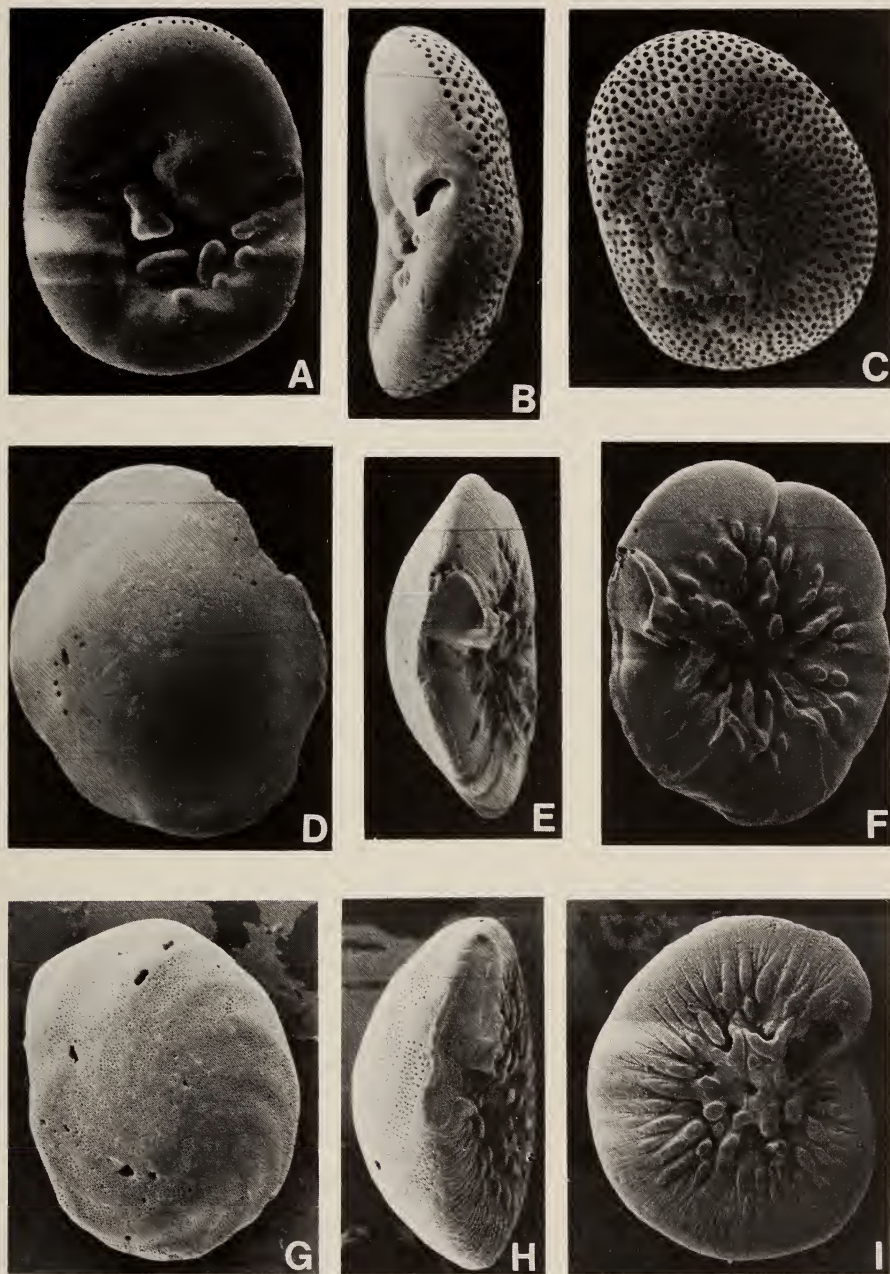Fig. 12. A–C. *Rosalina bradyi* (Cushman). A. Ventral view, CTC 4. × 139. B. Side view, same specimen. × 144. C. Dorsal view, same specimen. × 135. D–F. *Rosalina* sp. D. Dorsal view, CTC 3. × 125. E. Side view, same specimen. × 115. F. Ventral view, same specimen. × 120. G–I. *Glabratella australensis* (Heron-Allen & Earland). G. Dorsal view, CTC 4. × 81. H. Side view, CTC 4. × 130. I. Ventral view, CTC 4. × 107.

Rosalina sp.

Fig. 12D–F

Remarks

One specimen, closely comparable in its test morphology to *Rosalina williamsoni* (Chapman & Parr), but differing in a pronounced umbilical ornament. A similar form, less ornate, occurs on the Orange Shelf (McMillan 1987b—described as *Rosalina williamsoni*). The Orange Shelf shells display a variable, tuberculate ornamentation in and around the umbilicus, but the Cape Town test exhibits a stronger ornament of radiating, elongate-ovate flat-topped pillars and bosses.

North-west European examples of *Rosalina williamsoni* (see Rosset-Moulinier 1972, pl. 9 (fig. 32); Haynes 1973a, pl. 17 (fig. 13), text-fig. 31 (no. 3)) feature a relatively unornamented umbilicus, with just occasional bosses or tubercles on the umbilical terminations of the chambers in the final whorl, and within the umbilicus itself. In contrast, the tests figured by Boltovskoy *et al.* (1980, pl. 12 (figs 5–12)) from the coast of Argentina as *Discorbis williamsoni* appear in fact more closely allied to *Gavelinopsis praegeri* (Heron-Allen & Earland), since the umbilicus is infilled with a distinct plug. It seems probable that the *Discorbis* cf. *D. valvulatus* (d'Orbigny) of Boltovskoy *et al.* (1980, pl. 12 (figs 1–4)) is conspecific with *Rosalina williamsoni* sensu McMillan (1987b). Some similarity, in terms of style of ornamentation, exists between the Orange Shelf tests and *Rosalina malovensis* (Heron-Allen & Earland) from the seas around the Falkland Islands. However, none of the southern African shells feature such elongate, crescentic chambers, evident on both dorsal and ventral sides of the test, as exist in *Rosalina malovensis*.

The radiating ornament around the umbilicus of both the Cape Town and Orange Shelf forms perhaps shows some similarity to *Rosalina parri* Collins (1974, pl. 3 (fig. 36a–c)). However, this Australian species is only slightly bedecked with pillars around the umbilicus; more evident are the radiating grooves and ridges that cover nearly all the ventral side of the illustrated test. Radiating ornament around the umbilicus has been one of the characteristics of the family Glabratellidae of Loeblich & Tappan (1964: C587), but the last chamber of many of the southern African tests of this group clearly extends a small triangular flap into the umbilical area, a feature that is rather more typical of *Rosalina* than *Glabratella*.

Family **Bagginidae** Cushman, 1927

Genus *Glabratella* Dorreen, 1948

Glabratella australensis (Heron-Allen & Earland, 1932)

Fig. 12G–I

Discorbina pileolus (*non* d'Orbigny) Brady, 1884: 469, pl. 89 (figs 2–4).
Discorbis australensis Heron-Allen & Earland, 1932: 416. Parr, 1939: 68.
Glabratella australensis (Heron-Allen & Earland) McMillan, 1987b: 363, pl. 14 (figs 14–18), pl. 15 (figs 1–2).

Remarks

A common littoral species along most of the South African coastline at the present day (Brady 1884), extending at least from Cape Town to Mzamba, Transkei (unpubl. studies). It has also been widely recorded along the south, south-east and south-west coasts of Australia (Brady 1884; Chapman 1909; Parr 1945; McKenzie 1962; Albani 1968a, 1968b; Johnson & Albani 1973; Collins 1974; Albani & Johnson 1975) and off New Zealand (Mestayer 1916; Cushman 1919). Its fossil range in Australia appears to be Middle Pliocene (Kalimnan) (Parr 1939), Pleistocene (Collins 1953), and present day. In contrast, in South Africa, it is confined to the Pleistocene, being extremely rare or absent in the earliest Pleistocene (Unit II) of the 'Alexandria Formation', and only coming into prominence in the later Early Pleistocene (Unit IIA) of the 'Bredasdorp Formation'. *Glabratella australensis* occurs in considerable numbers at some localities of the Varswater Formation (probably Unit IIA), particularly at Hoedjiespunt, Saldanha.

The species is distinguished from the South American *Glabratella pileolus* (d'Orbigny) in its larger number of chambers per whorl ('eight or more' rather than 'four or five'—Heron-Allen & Earland 1932: 416), its shallower umbilicus, and its somewhat compressed, low-spired test. Living specimens of *Glabratella australensis* from intertidal pools at Camps Bay and elsewhere on the north-west Cape Peninsula are a strong greenish brown in colour; perfect, unabraded tests are spectacular when viewed under the scanning electron microscope (see McMillan 1987b, pl. 14 (figs 14–18)). Tests from the Cape Town city centre samples are rather abraded, and much of the detail of the ventral ornamentation of radiating ridges and tubercles has been smoothed.

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Family **Anomalinidae** Cushman, 1927

Subfamily Cibicidinae Cushman, 1927

Genus *Cibicides* De Montfort, 1808

Cibicides fletcheri Galloway & Wissler, 1927 s.l.

Fig. 13A–C

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Cibicides fletcheri Galloway & Wissler, 1927: 64, pl. 10 (figs 8a–c, 9a–c). Lankford & Phleger, 1973: 117, pl. 6 (figs 11a–c).
Cibicides cf. *C. fletcheri* Galloway & Wissler. Boltovskoy *et al.*, 1980: 24, pl. 8 (figs 17–21).

Remarks

Three rather damaged tests, compressed, and characterized by a small, rounded, domed umbilical infilling on the ventral side, and a flat and wide boss, flush with the test surface, in the dorsal umbilicus. These tests are similar to those detailed by McMillan (1987b) from the latest Eemian–earliest Weichselian and Holocene of the Orange Shelf.

The correct taxonomic name for this form is difficult to determine; so many similar, though distinctly different morphotypes have been assigned to Galloway
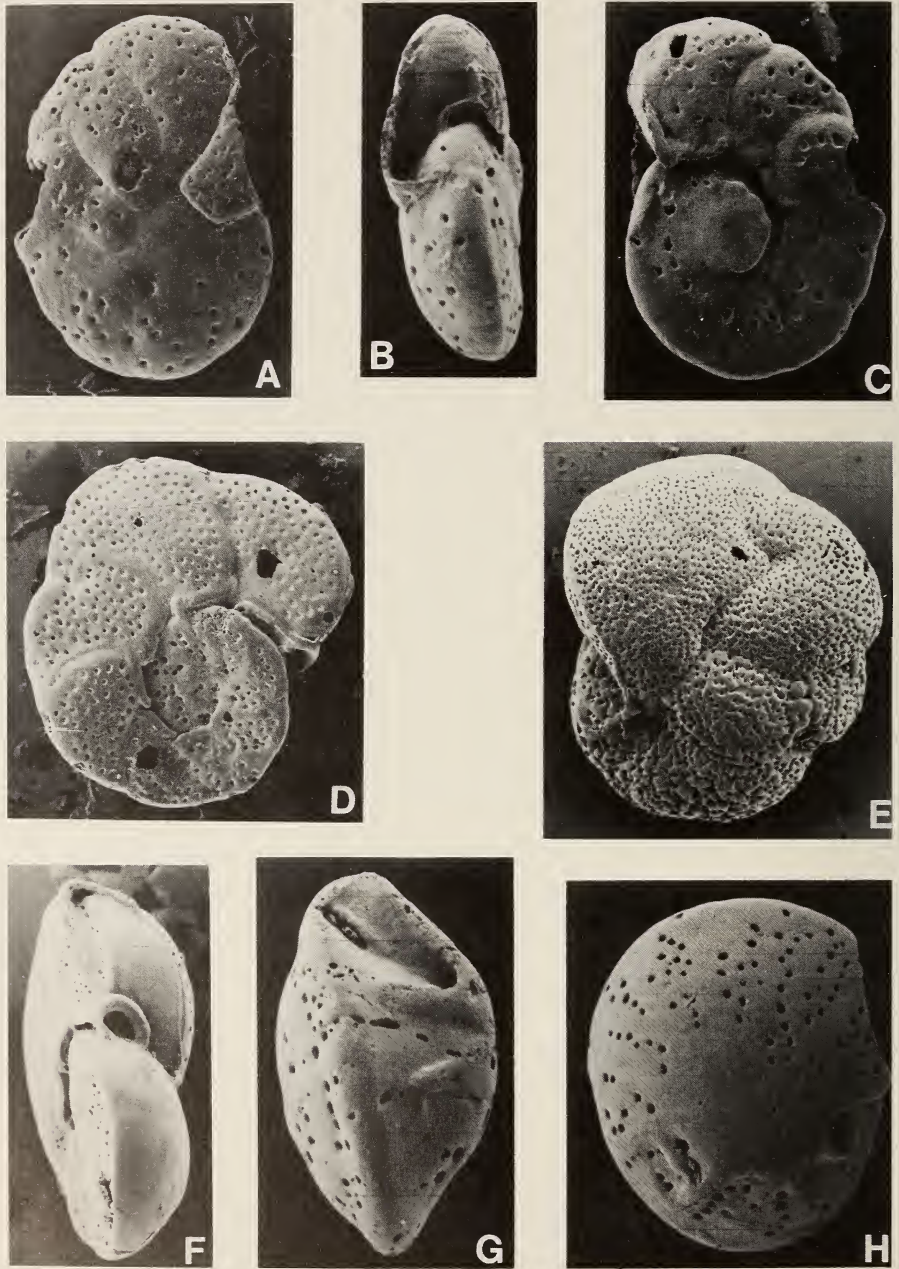
Fig. 13. A–C. *Cibicides fletcheri* Galloway & Wissler s.l. A. Ventral view, CTC 3. × 174. B. Side view, same specimen. × 168. C. Dorsal view, same specimen. × 174. D–F. *Cibicides lobatulus* (Walker & Jacob). D. Dorsal view, CTC 4. × 88. E. Ventral view, CTC 4. × 82. F. Side view, CTC 4. × 146. G–H. *Cibicidoides* sp. G. Side view, CTC 3. × 84. H. Ventral view, CTC 2. × 129.

& Wissler's (1927) species that it is unclear what the limits of the species should be. A comparable species is *Anomalina schmitti*, described by Cushman & Wickenden (1929) from present-day sediments off Juan Fernandez Islands, off the west coast of South America. It is not clear how distinct are these two species. *Cibicides fletcheri* was first described by Galloway & Wissler (1927) from the Pleistocene of the Palos Verdes Hills of California.

Cibicides lobatulus (Walker & Jacob, 1798)

Fig. 13D–F

Nautilus lobatulus Walker & Jacob, *in* Kanmacher, 1798: 642, pl. 14 (fig. 36).
Cibicides lobatulus (Walker & Jacob) Murray, 1971: 175, pl. 73 (figs 1–7). Haynes, 1973*a*: 173,
    pl. 20 (figs 1–2), pl. 21 (figs 3, 5–6), pl. 33 (figs 1–7), text-fig. 35 (nos 4–10). Boltovskoy
    et al., 1980: 24, pl. 9 (figs 1, 3–4, ?2). Martin, 1981: 52, pl. 5 (figs 4–6).

Remarks

    All tests possess narrow, elongate chamber flaps over the spiral suture, from under which the secondary apertures are developed on the dorsal sides of the final whorl of chambers. The shape of the flaps along the spiral suture is in keeping with those seen on tests from the latest Pleistocene and Holocene of the Orange Shelf (McMillan 1987*b*), off the west coast of southern Africa (Martin 1981), on the Agulhas Bank (McMillan 1974—though not well drawn on pl. 8 (fig. 1c)), and off the coast of Argentina (Boltovskoy *et al.* 1980). However, north-west European tests (the type locality is Whitstable in Kent) tend to possess rather more lobate chamber flaps (Feyling-Hanssen 1964; Knudsen 1971; Murray 1971; Rosset-Moulinier 1972; Haynes 1973*a*). The difference is slight but it may prove to be consistent between the two regions.

    As with the latest Pleistocene and Holocene tests of *Cibicides lobatulus* from the Orange Shelf (McMillan 1987*b*), there are substantial differences in the density of test perforations and in the overall test morphology of the Cape Town shells. Spreading, more rounded-conical forms, often with a distinct peripheral thickening, are usually densely perforate over the entire ventral side. The higher, button-shaped, more biconvex tests, with a more rounded periphery and little thickening, are generally only sporadically perforate on the ventral side, more so over the surface of the earlier chambers.

Genus *Cibicidoides* Thalmann, emend. Loeblich & Tappan, 1955

Cibicidoides sp.

Figs 13G–H, 14A–B

Remarks

    All tests of this species are rather broken. All are coarsely perforate on both sides of the test, and exhibit ventral sutures that are more radiate and
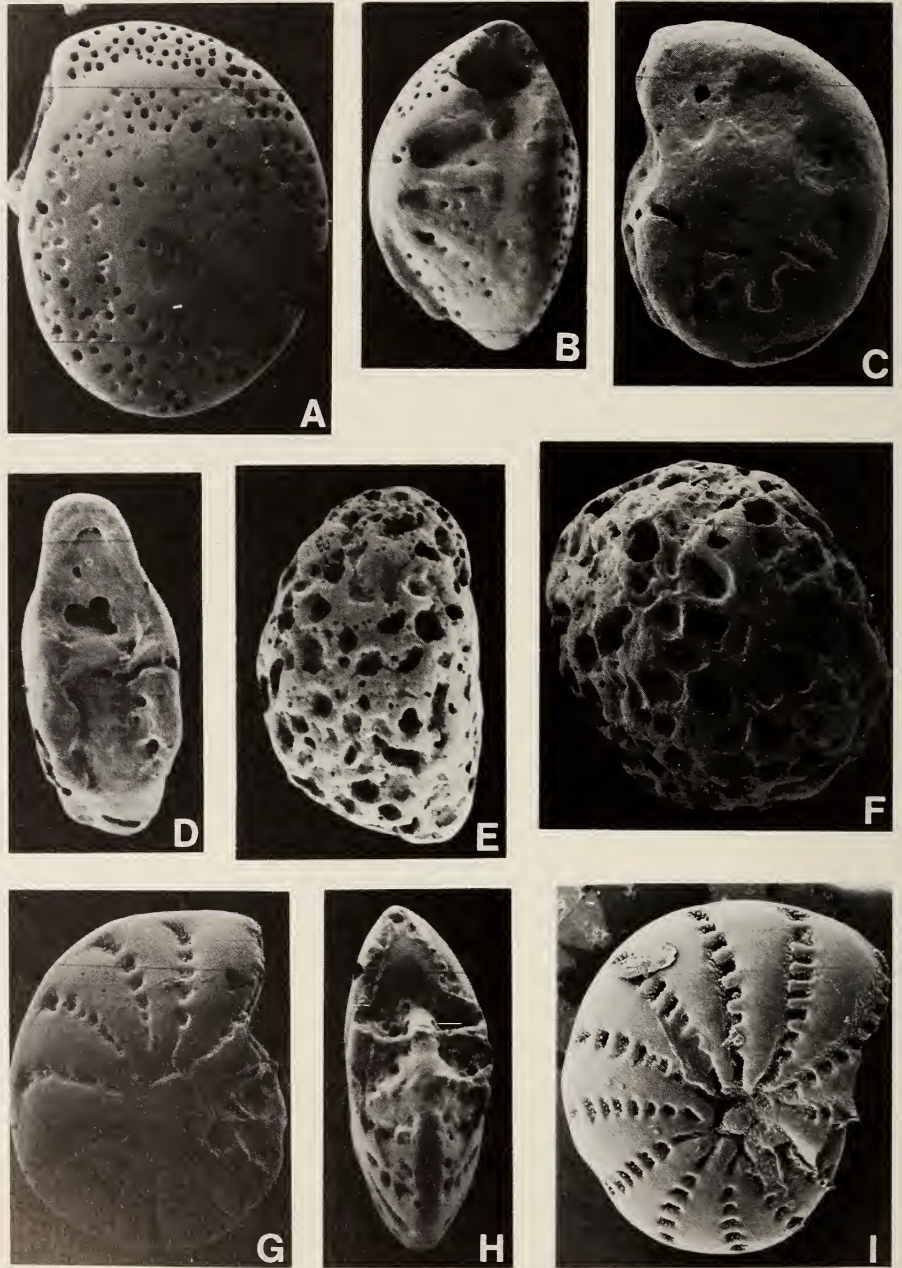
Fig. 14. A–B. *Cibicidoides* sp. A. Dorsal view, CTC 2. × 112. B. Side view, same specimen as Figure 13H. × 120. C–D. *Hyalinea balthica* (Schröter). Side view, CTC 3. × 205. D. Apertural view, same specimen. × 205. E–F. *Sphaerogypsina globulus* (Reuss). Different views of the same specimen, CTC 3. E. × 137. F. × 144. G–H. *Elphidium advenum* (Cushman). G. Side view, CTC 3. × 144. H. Apertural view, same specimen. × 146. I. *Elphidium* sp. A. Side view, CTC 4. × 120.

straight or weakly curved than is typical of the type species, *Cibicidoides mundulus* (Brady, Parker & Jones), which is coarsely perforate only on the dorsal side. This type of *Cibicidoides* is not known from the Orange Shelf (McMillan 1987*b*), and would seem closer to the *Cibicides* cf. *C. praecinctus* (Karrer) of McMillan (1974) from the Agulhas Bank and Martin (1981) from scattered western offshore localities. These tests are distinctly more biconvex than is typical for *Cibicidoides pseudo-ungerianus* (Cushman), widely found off both the south and west coasts of southern Africa (McMillan 1974; Martin 1974, 1981).

Subfamily Planulininae Bermúdez, 1952
Genus *Hyalinea* Hofker, 1951

Hyalinea balthica (Schröter, 1783)

Fig. 14C–D

Nautilus balthicus Schröter, 1783: 20, pl. 1 (fig. 2).
Hyalinea balthica (Schröter) Murray, 1971: 173, pl. 72 (figs 5–8).
Hyalinea balthica (Gmelin) Bremer *et al.*, 1980: 23, pl. 3 (fig. 8).

Remarks

One specimen, rather broken and with tubular borings. The specimen is typical for the species, which occurs widely over the western continental margin of southern Africa at the present day (Pinto 1955; Martin 1974, 1981), as far south as the westernmost Agulhas Bank (McMillan 1974). *Hyalinea balthica* ranges throughout the latest Eemian–earliest Weichselian and Holocene deposits of the Orange Shelf (McMillan 1987*b*). It is known from the latest Eemian–earliest Weichselian sediments of the Agulhas Bank (borehole F–A 13) (McMillan 1986), and at that time ranged as far east as Algoa Bay, where it is seen in the coastal Unit III of the 'Alexandria Formation' (Rümke *in* Engelbrecht *et al.* 1962; Salmon 1981; McMillan in press).

In the latest Eemian–earliest Weichselian Unit III, *Hyalinea balthica* occurs in littoral sands but, in the Holocene and at the present day, the species is more typical of middle to outer shelf environments and deeper; Martin (1981) gave its depth range as 92 m to 995 m off the west coast. As is the case with the Cape Town test, latest Pleistocene shells would appear to be slightly thicker walled than those from the Holocene, but there seems to be no distinct morphological difference.

Hyalinea balthica has not been found in earlier Pleistocene deposits in South Africa, though this may be due to the depositional facies of the rocks. Certainly, though, the species cannot be considered as a marker for the Pliocene–Pleistocene boundary on the continental shelf of southern Africa, as has been done elsewhere (see Bayliss 1969).

Family **Acervulinidae** Schultze, 1854
Genus *Sphaerogypsina* Galloway, 1933

Sphaerogypsina globulus (Reuss, 1848)

Fig. 14E–F

Ceriopora globulus Reuss, 1848: 33, pl. 5 (fig. 7a–c).
Sphaerogypsina globulus (Reuss) Loeblich & Tappan, 1964: C698, fig. 569 (nos 1–2).

Remarks

Several subspherical tests, although damaged, some with a flattened surface
that may have attached to a substrate, are referable to this species. One or two
examples were seen in the latest Pleistocene deposits of the Orange Shelf
(McMillan 1987b), but the species is more numerous in the Cape Town samples.
In most of the studied tests, the thin perforated walls over each chamberlet are
usually damaged or entirely worn away, and only the thicker intercameral walls
remain visible, as in the illustrated test. Similar forms, though larger and more
nearly spherical, occur in the Early Miocene (Burdigalian) shelly, white lime-
muds at a number of localities on the South African continental margin.

Family **Elphidiidae** Galloway, 1933
Subfamily Elphidiinae Galloway, 1933
Genus *Elphidium* De Montfort, 1808

Elphidium advenum (Cushman, 1922)

Fig. 14G–H

Polystomella subnodosa (*non* Münster) Brady, 1884: 734, pl. 110 (fig. 1a–b).
Polystomella advena Cushman, 1922: 56, pl. 9 (figs 11–12).
Elphidium advenum (Cushman) Albani, 1968a: 111, pl. 10 (fig. 6).
see *Elphidium advena* (Cushman) Apthorpe, 1980: 211, pl. 26 (figs 10–11).

Remarks

Most later authors studying Indo-Pacific material appear to have followed the
illustrations of Brady (1884) rather than those given by Cushman (1922) for their
identification of *Elphidium advenum*. The septal pits of Indo-Pacific tests of the
species are short and never as elongate as those of the holotype, which is from the
Tortugas region of the West Indies. It may be, as suggested by Cushman (1922),
that the Indo-Pacific shells assigned to this species are of a slightly different form
than the tropical Atlantic *Elphidium advenum* s.s.

From studies of the 'Alexandria Formation' of the eastern Cape (McMillan
in press), it is clear that *Elphidium advenum*, as here understood, ranges from the
present day to near the base of the Pleistocene (and includes Unit II). It can thus
be considered as a useful marker species for the South African Quaternary, in
company with *Pararotalia nipponica* (Asano) and *Cibicides lobatulus* (Walker &
Jacob). The species is extensively distributed off the west, south and east coasts
of southern Africa at the present day, and tends to predominate in shallow marine

environments (Albani 1965; Martin 1981; unpubl. studies), although off the west coast it ranges into waters as deep as 418 m (Martin 1981), and small numbers of specimens occur as deep as 127 m on the Agulhas Bank (McMillan 1974). It was also widely distributed in latest Eemian–earliest Weichselian times in shallow marine environments around southern Africa, from the Orange Shelf (McMillan 1987b) to the Uloa Formation.

Elphidium sp. A
Fig. 14I, 15A

Elphidium advenum (*non* Cushman) McMillan, 1987b, pl. 17 (figs 1–2).

Remarks

A small proportion of the tests, initially assigned to *Elphidium advenum* by McMillan (1987b), lack the distinctive peripheral carina and wide, flat-topped and flush umbilical boss of that species. Instead, the umbilical boss is small, almost like a pinhead, and sited in a narrow umbilicus that is not entirely occupied by the boss. The later chambers are slightly inflated, the test size is somewhat greater, and the septal pits are more sharply defined, rather deeper, and more elongate than true *Elphidium advenum*.

Elphidium sp. A is apparently confined to the latest Pleistocene of the west coast, and is absent in the Holocene. The differences from true *Elphidium advenum* are sufficient for this form to be considered a separate, possibly new species but insufficient specimens occur in the Cape Town samples for a formal taxon to be erected here.

Elphidium articulatum (d'Orbigny, 1839)
Fig. 15B–C

Polystomella articulata d'Orbigny, 1839b: 30, pl. 3 (figs 9–10).
Elphidium articulatum (d'Orbigny) Boltovskoy, 1963: 61, pl. 6 (fig. 15). Boltovskoy *et al.*, 1980: 29, pl. 13 (figs 1–4).

Remarks

Distinct, though slight differences exist in the style of the umbilical ornamentation of Cape Town tests compared with those illustrated by McMillan (1987b) from the Orange Shelf. The Orange Shelf examples reveal a rather depressed umbilicus ornamented with 20 or more thin calcite pillars. In the illustrated Cape Town shell, there are no more than ten pillars, and these are often merged together, or with the umbilical terminations of the chambers; they also tend to be larger in size than the pillars of the Orange Shelf tests. The septal pits, both in their numbers and outline, the style of the aperture, the number of chambers in the final whorl, the chamber morphology and the overall test morphology of the Orange Shelf and Cape Town tests are all closely comparable. Those from Cape Town show an umbilical arrangement somewhat closer to the
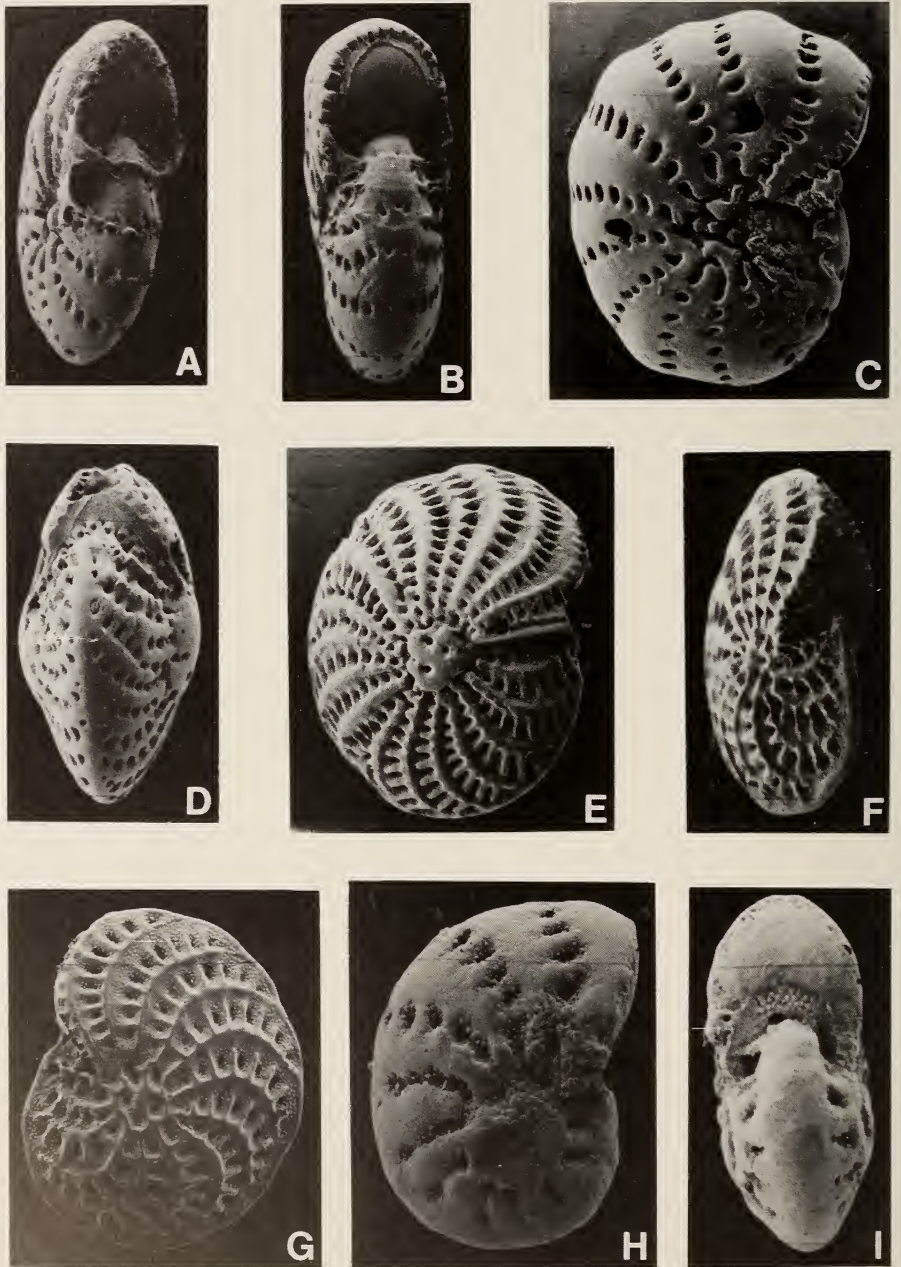
Fig. 15. A. *Elphidium* sp. A. Oblique apertural view, same specimen as Figure 14I. × 113.
B–C. *Elphidium articulatum* (d'Orbigny). B. Apertural view, CTC 4. × 84. C. Side view,
same specimen. × 86. D–E. *Elphidium crispum* (Linné) s.l. D. Apertural view, CTC 4.
× 79. E. Side view, CTC 4. × 83. F–G. *Elphidium macellum* (Fichtel & Moll) s.l. F. Oblique
apertural view, CTC 4. × 95. G. Side view, same specimen. × 95. H–I. *Elphidium* sp. B.
H. Side view, CTC 3. × 178. I. Apertural view, same specimen. × 178.

individuals illustrated by Boltovskoy *et al.* (1980) from the coast of Argentina. However, the Argentinian tests are more strongly biconvex than those from southern Africa, if the apertural view (Boltovskoy *et al.* 1980, pl. 13 (fig. 3)) can be regarded as typical.

D'Orbigny (1839*b*) figured a specimen that is substantially more lobate around the test periphery than is the case in more recently illustrated South Atlantic tests; his specimens were from the Río Negro coast of Patagonia and from off the Falkland Islands. *Elphidium articulatum* appears to range from the latest Eemian–earliest Weichselian to the present day in southern Africa. It is typical of innermost shelf, cold-water locations on the west coast, and occurs in the present-day sands washed into the canalized mouth of the Soutrivier, just north-east of Cape Town city centre.

<div align="center">

Elphidium crispum (Linné, 1758) s.l.

Fig. 15D–E
</div>

Nautilus crispus Linné, 1758: 709 (figured by Plancus, 1739, pl. 1 (fig. 2d–f)).
Elphidium crispum (Linné) Cushman & Leavitt, 1929: 20, pl. 4 (figs 3a–b, 4a–b). Hageman,
   1979: 94, pl. 5 (fig. 6a–b).

Remarks

Preliminary details of the taxonomic complexity surrounding this species and *Elphidium macellum* (Fichtel & Moll), and the relationship of these two Mediterranean species to comparable southern African forms, were given by McMillan (1987*b*). The following are supplementary notes.

Examination of authors' illustrations of *Elphidium crispum* from the Mediterranean Sea shows a wide range of forms. All the original figures are somewhat stylized drawings (Plancus 1739; Gualtieri 1742), and it is upon these that Linné based his concept of this species. The tests detailed by Gualtieri appear to display an immense number of chambers in the final whorl, whereas those figured by Plancus seem to contain about 20 chambers.

Cushman & Leavitt (1929), in an attempt to distinguish clearly between *Elphidium macellum* and *Elphidium crispum*, re-examined the illustrations of both species as figured by Fichtel & Moll (1798), and compared these with specimens 'from as near the type locality as possible'. In the case of *Elphidium crispum*, it is worth including here Cushman & Leavitt's full description:

'Test of large size for the genus, about 2½ times longer than wide in peripheral view, lenticular, completely involute, the umbilical regions with a medium sized, slightly projecting, rounded boss of clear shell material, the surface of which is set with 10–12 small, shallow, rounded pits, periphery sharply angular but not sharply keeled, sometimes becoming slightly lobulate and blunter in the last portion of the adult coil; chambers very numerous, 20–40 in number, long, narrow, the last few often inflated, forward part slightly raised, giving a radially ribbed appearance; sutures somewhat sigmoid, the middle portion of each nearly

radial, partially obscured by the retral processes, set with pores, those of the earlier ones indistinct but later ones with large and deep pores; wall finely perforate with about 12 relatively long retral processes extending well up onto the side of the next added chamber, appearing as fairly widely spaced, low elevations of the wall in the earlier chambers, but as thicker and more rod-like structures in the later chambers; aperture, a row of small openings between the retral processes at the base of the apertural face, which is low, sagittate, the sides often slightly concave, the ends pointed. Diameter up to 3 mm.'

Such large-sized tests of *Elphidium* occur nowhere in South Africa, living or fossil. South African tests assigned to this species possess only from 17 to 22 chambers in the final whorl of adult specimens, whereas juvenile examples reveal rarely more than 12. The South African individuals tend to be more biconvex rather than lenticular, normally with a small, sharply defined, well-raised umbilical boss that exhibits a maximum of seven pits on its surface, rather than the 10–12 described by Cushman & Leavitt (1929). Closer similarity would seem to exist between the style and numbers of the septal pits and bridges, though perhaps the tests figured by Cushman & Leavitt (1929) are a little stylized in this respect.

South African shells feature a rounded to weakly sub-rounded, never acute, test margin that reveals a hint of thickening along the earlier part of the final whorl, whereas the periphery of the Italian form is sharply angular. However, some latest Pleistocene tests of *Elphidium crispum* clearly show abrasion along the periphery, which in severe cases may wear through to the chamber cavities. It thus seems likely that the test periphery has been substantially amended on occasion by post-mortem transport, probably through rotating and cartwheeling of these shells in the littoral sands before final deposition. Nevertheless, despite the probability of some post-mortem changes to these *Elphidium crispum* shells, there are clearly distinct differences between southern African and Mediterranean tests. Although the differences are not great, and the southern African examples clearly fall within *Elphidium crispum* s.l., nevertheless they can be confidently regarded as a local, distinctive form, which is easily distinguished from *Elphidium crispum* s.s.

Unfortunately, this fairly simple picture is complicated by authors' changing attitudes to species through the twentieth century. Cushman & Leavitt (1929) evidently based their descriptions on adult specimens only, for they noted that a considerable difference exists between the test morphologies of microspheric and megalospheric, and juvenile and adult tests of both *Elphidium crispum* and *Elphidium macellum*; these changes mostly remain to be documented. Thus, for Cushman & Leavitt (1929), the two species are easily distinguishable, but later authors have tended to see the two as end-members with substantial variation between them. In addition, later authors' illustrations are of smaller-sized (?juvenile) tests, e.g. Kruit (1955, pl. 2 (fig. 10)) from the Rhône delta, Hageman (1979, pl. 5 (fig. 6a–b)) from

the Plio–Pleistocene of the western Peloponnesus of Greece, and Jonkers (1984, pl. 12 (fig. 4)) from the Pliocene of Crete. Hageman (1979) reported on a continuous gradation from lenticular tests with a large umbilical boss (typical *Elphidium crispum*) to compressed tests lacking or possessing a small umbilical boss (closely resembling typical *Elphidium macellum*), and Jonkers (1984) followed similar methods of interpretation. Despite this rather confusing picture of Mediterranean *Elphidium crispum*, the South African tests appear to remain distinct from the species in a strict sense. However, to avoid increasing the range of names available for this group of *Elphidium*, the southern African tests are here referred to *Elphidium crispum* s.l.

Elphidium crispum s.l. occurs in large numbers in the Cape Town samples and elsewhere around the south-western Cape coast in deposits of the same age (see Appendices A to C). The species is not found in deposits older than latest Eemian–earliest Weichselian in the South African Pleistocene, though similar species, of the *Elphidium crispum–macellum* group, occur in both the Varswater Formation and in the older 'Bredasdorp Formation' (both Unit IIA). *Elphidium crispum* s.l. became extinct during the Weichselian or at the end of the Pleistocene, and it is not found *in situ* in any Holocene deposits in South Africa.

This species occurs in smaller numbers in the latest Eemian–earliest Weichselian of the Orange Shelf (McMillan 1987*b*) than at Cape Town. It is also present close to the coast in the youngest parts (Unit III) of the 'Bredasdorp Formation' and the 'Alexandria Formation', at Plettenberg Bay, and on the Agulhas Bank (McMillan 1974); on the inner shelf it may occur in considerable numbers, reworked into the Holocene. The species is also known from the Aliwal Shoal (Carter 1966) and the Uloa Formation of Zululand (pers. obs.), but there are slight morphological differences evident in these warmer-water tests that have yet to be defined. *Elphidium crispum* s.l. thus seems to be an ideal zone fossil for all the littoral or sublittoral deposits of the latest Eemian–earliest Weichselian regression. It is restricted to the same time interval over which *Ammonia* sp. B (Alexandria) and *Ammonia* sp. C (Alexandria) range (McMillan 1987*a*), but is better developed in the colder waters of the west coast, where the two *Ammonia* species are absent (see Fig. 3).

Elphidium crispum s.l. tests from studied localities are invariably broken or abraded, and often the entire outer whorl of chambers is missing, leading to strongly raised umbilical bosses, which tend to better survive the abrasion processes. McMillan (1987*b*: 565) considered the possibility of *Elphidium crispum* s.l. and *Elphidium macellum* s.l. being abraded and clean tests, respectively, of the same species. On the Orange Shelf, the former is most common in the sandier, littoral parts of studied sections; the latter, always well preserved, is most frequent in the clayier intervals that presumably accumulated in quieter water conditions. There thus appears to be rather different facies controls on the two species. However, examination of the test outlines of the two, particularly their cross-sections, reveal distinct differences. Sectioned tests of *Elphidium macellum* s.l. are far too slender and lenticuline throughout their course of growth to

accommodate a kernel in their interior of the more strongly biconvex *Elphidium crispum* s.l. (or *vice versa*).

Elphidium macellum (Fichtel & Moll, 1798) s.l.

Fig. 15F–G

Nautilus macellus Fichtel & Moll, 1798: 66, var. β, pl. 10 (fig. h–k).
Elphidium macellum (Fichtel & Moll) Cushman & Leavitt, 1929: 18, pl. 4 (figs 1a–b, 2a–b).
　　Rögl & Hansen, 1984: 50, pl. 14 (figs 2, 5–6), pl. 15 (figs 1–2), text-fig. 18B.

Remarks

As with *Elphidium crispum* (Linné), local, southern African populations of *Elphidium macellum*, though closely similar to those from the type area of the Mediterranean Sea, nevertheless show some distinct and consistent differences. Cushman & Leavitt (1929), in their examination of *Elphidium macellum* from Rimini on the Adriatic coast of Italy, gave the following description:

'Test of medium size for the genus, about 3½ times longer than wide in peripheral view, lenticular, planispiral, completely involute, umbilical regions flat, periphery angular, slightly more rounded in the last-formed chambers, slightly keeled, somewhat lobulate; chambers numerous, averaging 17 in adults in the last-formed coil, slightly arched giving a ribbed appearance to the test; sutures slightly depressed, those of the last-formed chambers slightly more so, partially obscured by the retral processes, curved backward strongly toward the periphery, the proximal half nearly radial, set with indistinct pores; wall thin, finely perforate, usually with less than 12 relatively long retral processes, more widely spread than in *E. crispum* and extending from well up on the side of the chamber to the front of the preceding and appearing as narrow, fairly widely spaced, low elevations of the wall; aperture, a row of small openings between the retral processes at the base of the apertural face which is convex, sagittate, with the sides slightly convex, the lobes sharply angled, saddling the preceding coil. Diameter typically less than 1 mm; thickness 0,25 mm.'

Cushman & Leavitt (1929) concluded by distinguishing *Elphidium macellum* from *Elphidium crispum* and *Elphidium striatopunctatum* (Fichtel & Moll) by its keeled periphery that is often lobate, the fewer chambers in the final whorl, and the flattened or depressed umbilicus.

More recently, the Fichtel & Moll collections have been rediscovered in Vienna (Hansen & Rögl 1980), and a full re-appraisal of their species of 1798, including *Elphidium macellum*, has been achieved (Rögl & Hansen 1984). In the case of *Elphidium macellum* itself, Rögl & Hansen (1984: 51) described and illustrated a lectotype from the Fichtel & Moll collection, which thus must be regarded as the nomenclatural type. This specimen possesses a circular, non-lobate outline, a sharply angled and keeled periphery, 16 and a half chambers in the final whorl, curved sutures with 8 to 15 septal bridges per suture, slightly depressed umbilicus, lacking ornamentation or plug, apertural face low, sagittate, with fine tubercles, and interio-marginally an equatorially placed aperture

composed of multiple openings with small protruding lips; maximum diameter 0,79 mm; maximum thickness 0,32 mm.

On comparing the South African tests with the illustrations and descriptions of Rögl & Hansen (1984), it can be seen that the local tests differ in a number of skeletal features. These shells are more compressed, more slender than either the lectotype of Rögl & Hansen (1984) or the comparative Rimini tests illustrated by Cushman & Leavitt (1929). They contain from 13 to 19 chambers in the final whorl, with an apparent increase in numbers with increasing test size (McMillan 1987*b*). Most significantly, the umbilical area of the southern African tests is infilled with a low, irregular plug of varying size that is ornamented over its surface with one to seven pits, which in well-preserved examples can be seen to be spinose or tuberculate interiorly. The plug is never as large or as prominent as that seen in *Elphidium crispum* s.l. tests from the latest Pleistocene of south-western Africa, but it clearly shows variation in size and height (McMillan 1987*b*, pl. 18 (figs 1–6)). The southern African shells are also not quite as acutely carinate on the periphery of the test as the lectotype of Rögl & Hansen (1984). Because these differences in test morphology appear to be consistent distinctions between the Mediterranean and southern African tests, the latter are here termed *Elphidium macellum* s.l., for the same reasons as expressed for *Elphidium crispum* s.l.

It should be added that the southern African shells of *Elphidium macellum* s.l. compare closely, especially in their umbilical ornament, with some figured from the coast of Patagonia (Thomson 1978, pl. 2 (fig. 1)). The test illustrated by Brady (1884, pl. 110 (fig. 11a–b)) is of the same group, though the arrangement of pits over the surface of the umbilical infilling has not been found in so symmetrical a pattern in any of the southern African examples examined by the present author, and is perhaps a little stylized. Tests of this group have also been illustrated by Martin (1981, pl. 6 (fig. 12, and probably also fig. 10)) and McMillan (1974, pl. 9 (fig. 7a–b)).

Elphidium macellum s.l. ranges from the latest Eemian–earliest Weichselian (Unit III) deposits through to the present day around South Africa, and shows a slight preference for cooler water conditions. The species is also one of the group that occurs on the shelf during the Holocene (Martin (1981) gave its single occurrence in her samples as at 118 m water depth, and it was recognized by McMillan (1987*b*) between 137 m and 183 m on the Orange Shelf), but it is more typical of sublittoral, fairly quiet water conditions in the latest Pleistocene. Spinose juveniles, such as are typical of north-west European waters (see Haynes 1973*a*: 202, pl. 24 (figs 2–3)) do not occur in South Africa, either fossil or extant.

Elphidium sp. B

Fig. 15H–I

Remarks

One specimen, slightly reminiscent of *Elphidium gunteri* Cole, as described by McMillan (1987*b*) from the Orange Shelf but differing on several points. There

are 12 chambers in the final whorl, intersected by deeply incised, curved to straight, radiate sutures that are crossed by up to five septal bridges per side, the bridges appearing only on the later sutures. The umbilical chamber terminations are rounded and slightly nodose, and the umbilicus is fairly wide and shallow, being ornamented with a granular, almost sugary surface. The test wall is finely and densely perforate; the test periphery is broadly and uniformly rounded, the margin being sub-circular and continuous. The foramen, possibly composed of two arched interio-marginal openings at the base of the terminal face, is overlain by a zone of tuberculate ornamentation. *Elphidium gunteri* tests display a more lobate test periphery, coarser test wall perforations, less incised sutures, and an umbilical ornamentation of small numbers of irregularly shaped calcite pillars.

Genus *Astrononion* Cushman & Edwards, 1937

Astrononion echolsi Kennett, 1967

Fig. 16A–B

Astrononion echolsi Kennett, 1967: 134, pl. 11 (figs 7a–b, 8). Fillon, 1974: 139, pl. 6 (figs 1–3).
Astrononion stelligerum (*non* d'Orbigny) McMillan, 1987*b*: 422, pl. 19 (figs 1–3).

Remarks

A reconsideration of the *Astrononion* specimens described and illustrated by McMillan (1987*b*) from the latest Eemian–earliest Weichselian of the Orange Shelf suggests that they should rather be referred to the Antarctic species *Astrononion echolsi*.

Le Calvez (1974) has examined the type specimen of *Nonionina stelligera* d'Orbigny, found it to be unusable, and has proposed a neotype (Le Calvez 1974: 37, pl. 9 (figs 1–4)) from D'Orbigny's Canary Island (Teneriffe) specimens. The neotype is strongly compressed, with ten chambers in the last-formed whorl, deeply incised sutural slits outside of the umbilical cover plate(s), and a broad, shallow umbilicus almost entirely covered, except centrally, by the cover plate(s).

In contrast, the present specimen and those from the Orange Shelf possess only seven or eight chambers in the final whorl, rather more inflated chambers and a lobate test periphery, wider, more open and shorter incisions of the sutures, and a less extensive cover plate revealing more of the central umbilicus. The Cape Town specimen is a little more strongly biconvex than is typical for the Orange Shelf shells. This species would seem to be confined to the cold-water influenced latest Eemian and earliest Weichselian deposits of the west coast of South Africa.

Family **Rotaliidae** Ehrenberg, 1839

Genus *Ammonia* Brünnich, 1772

Ammonia japonica (Hada, 1931)

Fig. 16C–E

Rotalia japonica Hada, 1931: 137, fig. 93a–c.
Ammonia japonica (Hada) Matoba, 1970: 48, pl. 5 (fig. 14a–c), pl. 6 (fig. 1a–c). McMillan, 1987*a*: 37, text-fig. 7a–d.
Ammonia beccarii (*non* Linné) Martin, 1974: 84, fig. 14–1 (*part.*). Salmon, 1979: 77, fig. 3p. Martin, 1981: 48, pl. 3 (figs 2–3).
Ammonia beccarii (Linné) var. *inflata* (*non* Seguenza) McMillan, 1974: 62, pl. 6 (fig. 2a–c).

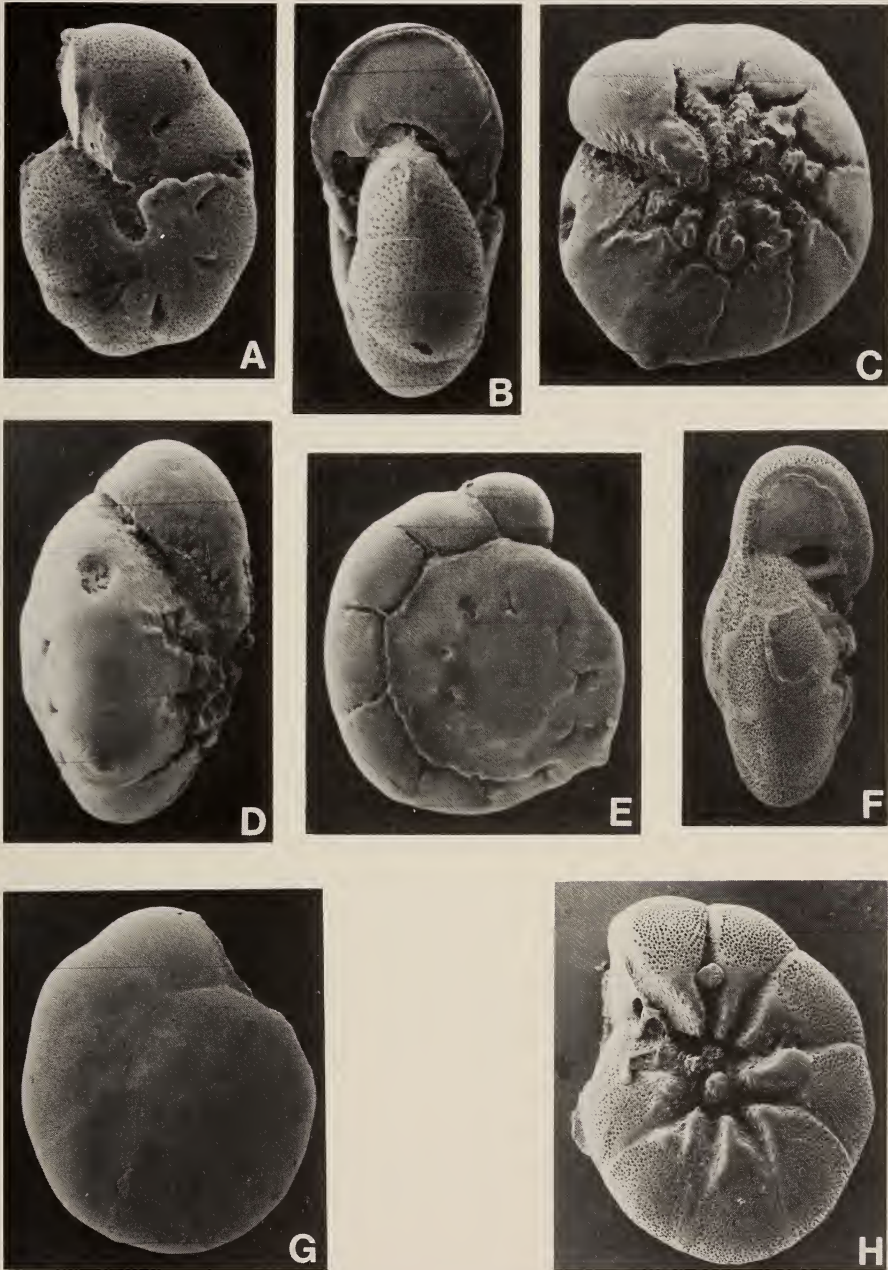Fig. 16. A–B. *Astrononion echolsi* Kennett. A. Side view, CTC 4. × 139. B. Apertural view, same specimen. × 157. C–E. *Ammonia japonica* (Hada). C. Ventral view, CTC 4. × 111. D. Side view, same specimen. × 124. E. Dorsal view, same specimen. × 110. F–H. *Ammonia parkinsoniana* (d'Orbigny) s.l. F. Side view, CTC 4. × 135. G. Dorsal view, CTC 4. × 111. H. Ventral view, same specimen as F. × 142.

Remarks

Subsequent to the comments on *Ammonia japonica* by McMillan (1987*a*, 1987*b*), additional studies have been made of the Pleistocene littoral deposits of the Saldanha–Langebaan region, the 'Bredasdorp Formation' and the 'Alexandria Formation' of the southern Cape coast, and the Uloa Formation and Bluff Sandstone Formation of Zululand/Natal. As was mentioned by McMillan (1987*a*), *Ammonia japonica* is best developed in the Holocene off the south and west coasts of South Africa, and is similarly distributed in the latest Eemian–earliest Weichselian (Unit III) deposits. The species is absent in older Pleistocene and Pliocene marine rocks of this region, although a similar form does occur in the Varswater Formation (Unit IIA) of the Langebaan–Saldanha area, that is of the same *Ammonia*-group as *Ammonia japonica*.

Holocene tests tend to possess numerous, rather granular calcite pillars in the umbilicus (Martin 1981, pl. 3 (fig. 2); McMillan 1987*b*, pl. 19 (figs 12, 15–16)), but latest Pleistocene shells are usually characterized by more robust umbilical pillars, which may often merge into sinuous, irregular structures (McMillan 1987*b*, pl. 20 (figs 1–2)). It is probable that the difference is due to abrasion of the Pleistocene tests but not the Holocene ones. However, variation in test morphology through time is also a possible cause.

Rouvillois (1974) described *Pseudoeponides falsobeccarii* from the continental shelf (60–120 m water depth) off the west of France, and it is clear that southern African *Ammonia japonica* is closely related to this North Atlantic species. Neither show much similarity to the genotype, *Pseudoeponides japonicus* Uchio (*in* Kawai *et al.* 1950). Rouvillois (1974) identified both ventral and dorsal openings in her species, but these are so unlike those of *Pseudoeponides japonicus* that, together with major differences in test and chamber morphology, it seems best for the moment to regard the French species as referable to *Ammonia*. The 'secondary openings' of the ventral side of *Ammonia falsobeccarii* occur in various forms in all species of *Ammonia*, but the dorsal openings, present also in southern African *Ammonia japonica*, clearly separate these two species from *Ammonia beccarii* (Linné) s.s., *Ammonia parkinsoniana* (d'Orbigny) s.l., and other species typical of more littoral environments. It may be that the deeper-water, shelf species of *Ammonia* warrant a distinct genus.

A comparison of southern African *Ammonia japonica* with *Ammonia falsobeccarii* evinces the following similarities and differences. Rouvillois' species possesses usually eight chambers, southern African tests display eight or nine, more rarely seven or ten, chambers in the final whorl. Both species possess very strongly convex ventral sides but the dorsal side of the southern African shells is always markedly convex, whereas that of the French species is weakly convex, almost flat. Variation in the arrangement and the style of the umbilical filling is similar, with well-preserved tests exhibiting a granular or tubercular ornament over the dense array of thin calcite pillars that occupy the umbilicus. The arrangement of incisions, bordered with granules and small nodes along the spiral and septal sutures, is much the same in both groups of specimens.

The detail of the secondary openings at the inner junctions of the septal and spiral sutures cannot be seen in the illustrations of *Ammonia japonica* given by Hada (1931) and Matoba (1967, 1970). Their figures appear to be derived from light microscope photography and drawings, and the depressions on the dorsal side may thus either be obscured by reflection effects within the shell, or they are absent in the Japanese tests. For the present, Hada's name has been retained for these southern African tests.

McMillan (1974) employed the name *Ammonia beccarii* (Linné) var. *inflata* (Seguenza) for this species on the Agulhas Bank. The dorsal sides of Agulhas Bank tests are generally less convex than those of tests from off the west coast (McMillan 1987a). *Rosalina inflata* was originally described by Seguenza (1862) from the 'Pleistocene abbastanza recente' clays of Catania, Sicily. Again, the ventral side of the test is strongly convex, the dorsal side less so. Some variation can be seen in the tests illustrated by Seguenza (1862, pl. 1 (figs 6, 6a–c)) but, although the umbilical ornamentation and the test outline are similar to southern African *Ammonia japonica*, the beaded bordered incisions of the sutures (in fig. 6b) may extend to the test periphery, and the ventral surfaces of the chambers may be strongly ornamented with irregular rugosities (figs 6a, 6c). Billman *et al.* (1980: 86, pl. 5 (figs 1–14)) have illustrated tests referred to *Ammonia inflata* (Seguenza) from northern Morocco, but noted that the species should be revised using topotypic material. The Moroccan tests possess incised sutures with beading over the entire ventral side; over the dorsal side the same ornamentation occurs, but it is less well developed along both septal and spiral sutures of the early part of the test. The umbilical infilling again consists of numerous calcite pillars. It is felt by the present author that *Ammonia inflata*, as understood by Seguenza (1862) or as differently interpreted by Billman *et al.* (1980), does not occur in southern Africa. The Agulhas Bank tests are hence regarded as *Ammonia japonica*, with a local variation being the less high trochospire of the tests compared to those seen off the west coast.

Although the species is known only as far back as the latest Eemian–earliest Weichselian in southern Africa, *Ammonia japonica* ranges back to the Early Pleistocene in Japan (Matoba 1967).

Ammonia parkinsoniana (d'Orbigny, 1839) s.l.

Fig. 16F–H

Rosalina parkinsoniana d'Orbigny, 1839a: 99, pl. 4 (figs 25–27).
Ammonia parkinsoniana (d'Orbigny) forma *tepida* Poag, 1978: 397, pl. 1 (figs 1–4, 10–12, 17–18).
Ammonia parkinsoniana (d'Orbigny) forma *typica* Poag, 1978: 397, pl. 1 (figs 5–9, 13–16, 19–21).
Ammonia beccarii (*non* Linné) Martin, 1981: 48 (*part.*).
Ammonia parkinsoniana (d'Orbigny) s.l. McMillan, 1987a: 35, figs 3a–r, 4–5.

Remarks

Extensively distributed around southern Africa in shallow marine environments in the Holocene and the latest Eemian–earliest Weichselian. The major morphological variations of the species in the southern African Holocene have been detailed by McMillan (1987*a*). *Ammonia parkinsoniana* s.l. occurs in the quieter water, clayier and siltier intervals, as well as the more active, sandier parts of the latest Pleistocene sections studied by McMillan (1987*b*) on the Orange Shelf.

Genus *Pararotalia* Le Calvez, 1949

Pararotalia nipponica (Asano, 1936)

Fig. 17A–C

Calcarina rotula (*non* Egger) Chapman, 1923: 3, pl. 1 (fig. 1).
Rotalia nipponica Asano, 1936: 614, pl. 31 (fig. 2a–c).
Rotalia ozawai Asano, 1951: 15, figs 115–117.
Pararotalia taiwanica (*non* Nakamura) Huang, 1964: 56, pl. 2 (fig. 2a–c).
Pararotalia sp. A Martin, 1974: 84, fig. 14–1 (*part.*).
Pararotalia cf. *P. inermis* (*non* Terquem emend. Le Calvez) McMillan, 1974: 63, pl. 6 (fig. 3a–c).
Pararotalia cf. *P. nipponica* (Asano) Martin, 1981: 48, pl. 9 (fig. 6).
Pararotalia nipponica (Asano) McMillan, 1987*b*: 443, pl. 20 (figs 13–17), pl. 21 (figs 1–3), text-fig. 9.

Remarks

Studies of the 'Alexandria Formation' (McMillan in press) indicate that *Pararotalia nipponica* ranges from the earliest Pleistocene (Unit II) to the present day; it is absent from the oldest, most inland part of the sequence (Early Pliocene, Unit I). In this respect it has a stratigraphic range comparable to *Cibicides lobatulus* (Walker & Jacob) and *Elphidium advenum* (Cushman).

Chapman's (1923) record of *Pararotalia nipponica* in the Late Cretaceous Mzamba Formation is clearly a contaminant from the overlying latest Pleistocene sands; similar tests, markedly different in their preservation to the *in situ* microfauna, were recognized by Makrides (1979). Neither *Calcarina* nor *Pararotalia*, nor any morphologically similar genera with peripheral blunt spines, are known anywhere in the South African Late Cretaceous.

The reference to *Rotalia dentata* Parker & Jones by Chapman (1907) from the ?latest Pleistocene of the Buffalo River, East London, almost certainly is referable here too. Siesser & Salmon (1979) reported '*Pararotalia inermis*', supposedly from the Late Eocene Langental Beds of southern Namibia, but samples from pits dug in these outcrops yielded no trace of Eocene *Pararotalia* species (unpubl. studies). The illustrations given (Siesser & Salmon 1979, fig. 15c–d) are certainly of *Pararotalia nipponica*. It is evident that these *Pararotalia* tests, in keeping with those of *Elphidium* and *Ammonia*, were introduced into the Langental region with windblown sand derived from the littoral. The presence of *Elphidium* cf. *E. crispum* (Linné) at Langental (Siesser
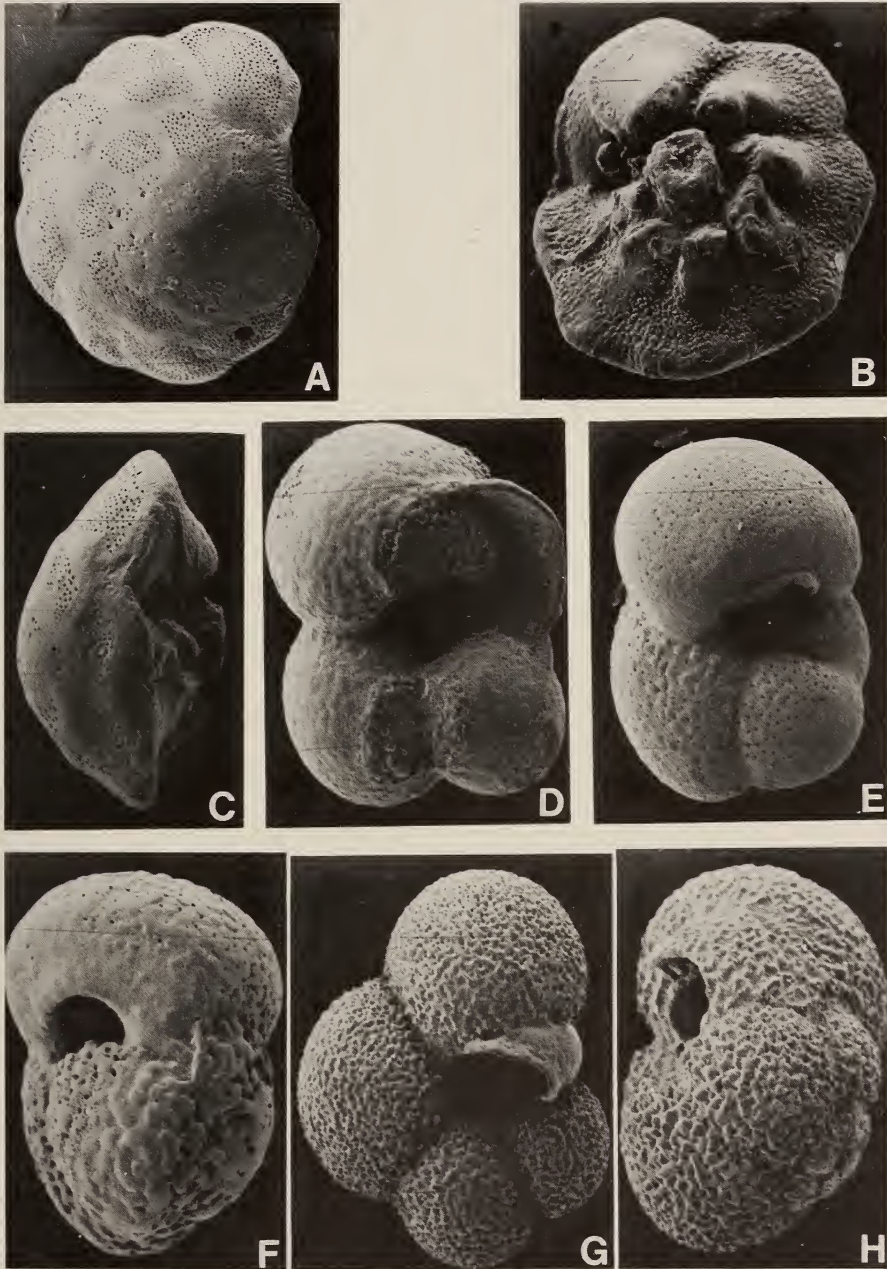
Fig. 17. A–C. *Pararotalia nipponica* (Asano). A. Dorsal view, CTC 4. × 98. B. Ventral view, CTC 4. × 122. C. Side view, same specimen as B. × 122. D. *Globigerina (Globigerina) bulloides* d'Orbigny. Ventral view, CTC 3. × 172. E–F. *Globorotalia (Globoconella) inflata* (d'Orbigny). E. Ventral view, CTC 3. × 181. F. Side view, CTC 3. × 235. G–H. *Neogloboquadrina* cf. *N. pachyderma* (Ehrenberg). G. Ventral view, CTC 3. × 200. H. Side view, CTC 3. × 275.

& Salmon 1979) perhaps suggests a latest Eemian–earliest Weichselian age for the windblown contaminants.

Pararotalia nipponica occurs in the Varswater Formation (McMillan 1987*b*, Appendix A) of the Langebaan area. It has also been reported as '*Rotalia*-like foraminifers' and '*Rotalia*' in the Saldanha area (Visser & Schoch 1973). The species is widespread throughout the 'Bredasdorp Formation' (unpubl. studies), and was noted by Rümke (*in* Spies *et al.* 1963) under the name *Rotalia audouini* d'Orbigny, though it is distinctly different from D'Orbigny's European Eocene and Oligocene species. In the 'Alexandria Formation' the species is widespread and abundant in the Early Pleistocene Unit II and latest Pleistocene Unit III— again previously recognized by Rümke (*in* Engelbrecht *et al.* 1962) as *Rotalia audouini*.

Specimens of '*Rotalia* sp.' from the Bluff Sandstone Formation at Durban, described by Parr (1958), are certainly referable to *Pararotalia nipponica*. Some of this material was stored on grid slides at the Bernard Price Institute for Palaeontological Research, University of the Witwatersrand, Johannesburg, and, through the courtesy of Professor M. Raath, were examined by the present author. *Pararotalia nipponica* also occurs, presumably *in situ*, in the latest Pleistocene (Unit III) *Pecten* bed in the lower half of the Uloa exposure, Zululand. As *Streblus taiwanica* (Nakamura), this species was encountered in Quaternary sands along the Inharrime to Vilanculos coast of Moçambique (Rocha 1965).

The *Pararotalia nipponica*-group exhibits wide morphological variation, particularly in the height of the trochospire, size of the umbilical boss, and in the spinose, lobate or circular test outline. Attempts to divide the latest Pleistocene tests into discrete morphological *formae* proved to be impossible for the Orange Shelf material (McMillan 1987*b*). However, there does seem to be one tendency toward tests with a high trochospire, circular or weakly lobate periphery, and large umbilical boss (*Pararotalia nipponica* form), and one tendency to low trochospire, spinose periphery, and small or divided umbilical boss (*Pararotalia ozawai* form). These two trends resemble the distinctions made by Ujiié (1966) within the group. Bhalla (1972) considered sexual dimorphism to be partly responsible for the wide range of morphologies included within *Pararotalia nipponica*.

Pararotalia nipponica is closely comparable to *Pararotalia serrata*, described by Ten Dam & Reinhold (1941) from the Pliocene of the Netherlands, and also known from similarly aged Crag deposits of eastern England (Funnell 1981). The precise differences between the two species remain to be determined.

Family **Globigerinidae** Carpenter, Parker & Jones, 1862
Genus *Globigerina* d'Orbigny, 1826
Globigerina (Globigerina) bulloides d'Orbigny, 1826

Fig. 17D

Globigerina bulloides d'Orbigny, 1826: 277, modèles no. 17 (1 ère livraison), no. 76 (4 ème livraison).

Remarks

Only brief notes are given for this and the following planktonic species. One test, with the last-formed chamber broken away. Compared with examples encountered in the Holocene of the Orange Shelf (McMillan 1987b), this test displays a rather low-arched aperture but is otherwise typical. The species is characteristic of subpolar and transitional waters in the world oceans (Bé & Tolderlund 1971). Kennett & Srinivasan (1983) regarded *Globigerina bulloides* to range from the Middle Miocene to the present day.

Family **Globorotaliidae** Cushman, 1927
Genus *Globorotalia* Cushman, 1927

Globorotalia (Globoconella) inflata (d'Orbigny, 1839)

Fig. 17E–F

Globigerina inflata d'Orbigny, 1839c: 134, pl. 2 (figs 7–9).

Remarks

Two specimens, one rather more lobate than is typical. Both are sinistrally coiled, as are almost all examples encountered by McMillan (1987b) through the Holocene of the Orange Shelf. The species is most typical of temperate water masses (Bé & Tolderlund 1971; Stainforth *et al.* 1975). Its stratigraphic range is Late Pliocene to present day (Kennett & Srinivasan 1983).

Genus *Neogloboquadrina* Bandy, Frerichs & Vincent, 1967

Neogloboquadrina cf. *N. pachyderma* (Ehrenberg, 1861)

Fig. 17G–H

see *Aristerosira pachyderma* Ehrenberg, 1861: 303; 1873: 386, pl. 1 (fig. 4).

Remarks

Two specimens of the shelf *forma* (non pachyderm), both sinistrally coiled and both exhibiting a kummerform final chamber. These tests show similarities to the shelf *forma* tests illustrated by McMillan (1987b, pl. 22, figs 14–16) from a water depth of 46,5 m, close to the Namaqualand coast. However, the presence of the kummerform final chambers result in distinctly unusual apertures, and the unique apertural arrangement of *Neogloboquadrina pachyderma* is not seen. For this reason, the two tests are placed in the status of confer *N. pachyderma*.

Sinistrally coiled *Neogloboquadrina pachyderma* appears to be associated with upwelling waters of the Benguela Current close to the west coast of southern Africa (Bé & Tolderlund 1971). The species ranges from the Late Miocene to the present day (Kennett & Srinivasan 1983).

trenching, for stratigraphy data on the samples, for much help in collecting the samples detailed in the three Appendices, as well as for valued discussions over many years on southern African Cainozoic and Mesozoic geology. Professor J. R. Haynes of University College of Wales, Aberystwyth, kindly made available facilities for sample processing, literature searching (including the Ellis & Messina 'Catalogue of Foraminifera'), photographic darkroom facilities, and allowed access to the U.C.W. scanning electron microscope, during completion of a Ph.D. thesis late in 1987. Comparative material from the Varswater Formation was supplied through the courtesy of Mr V. H. Valicenti and Dr A. J. Tankard (formerly South African Museum), from the 'Bredasdorp Formation' by Mr J. Malan (Geological Survey, Bellville), and from the 'Alexandria Formation' by Messrs D. Stear and W. Smuts (both formerly University of Port Elizabeth). Material from the Bluff Sandstone Formation was kindly provided by Mr J. A. G. Cooper (University of Natal), and some Uloa Formation material generously supplied by Mr G. Kruger (Industrial Development Corporation).

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APPENDIX A

THE LLANDUDNO–SANDY BAY COAST, CAPE PENINSULA

Deposits of the same age as those described in the main body of this article occur intermittently around the Cape Peninsula. Along the Llandudno to Sandy Bay part of the coastline, 'raised beach' deposits occur about 10 m above present
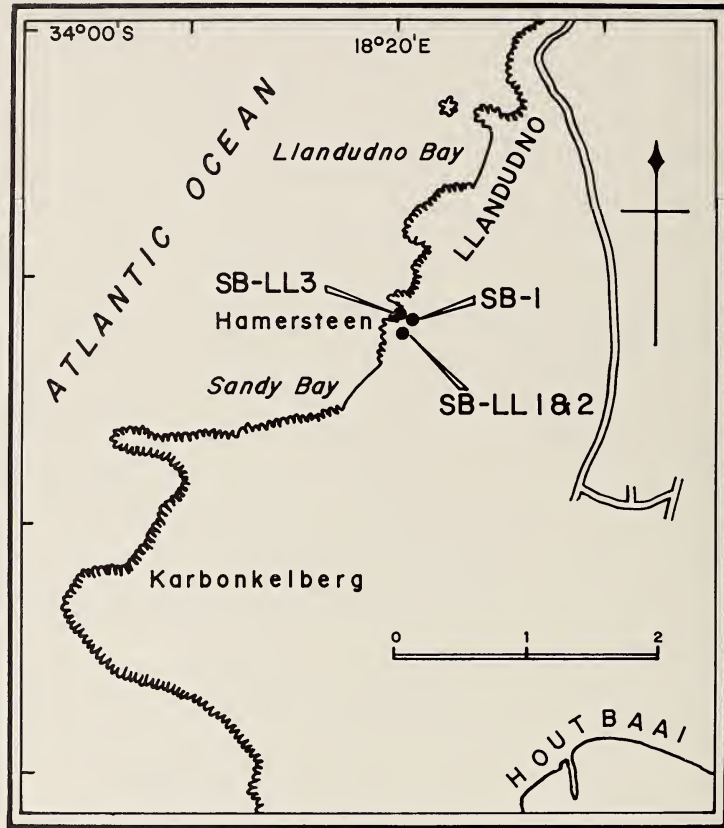
Fig. 18. Locality map of sampling sides along the Llandudno to Sandy Bay coast, Cape Peninsula.

mean sea-level as unconsolidated, white shelly sands at 34°01′05″S 18°20′00″E, just north of the Hamersteen (Fig. 18).

Because of their loose nature, they are poorly exposed and tend to wash down slope, but occasional clear faces may be seen or excavated on either sides of paths leading inland from, and parallel to the beach. Large shells, particularly gastropods, are common and often well preserved. Three samples were collected from the best available exposures late in 1986, and revealed the presence of abundant, though rather poorly preserved, often leached, and abraded foraminifera tests (sample SB–LL 3).

In addition, cemented shelly sandstone was noticed occasionally adhering to the large granite slabs and boulders in the present-day surf zone. One sample of sandstone revealed a microfauna very similar in composition to that of the 'raised beach' deposits, but severely affected by calcite leaching and precipitation, and somewhat less diverse.

The foraminiferal faunas of the four samples are closely comparable, both in species and composition, to those from Cape Town city centre. It is clear that these deposits near Llandudno are derived from the same regressional episode during the latest Eemian–earliest Weichselian. The faunas are distinguished by the predominance of *Elphidium crispum* (Linné) s.l., *Pararotalia nipponica* (Asano) and *Cibicides lobatulus* (Walker & Jacob), the first-named confirming the Unit III, latest Pleistocene age. Table 2 details the foraminifera recovered from the four samples.

The absence of *Ammonia parkinsoniana* (d'Orbigny) s.l. in the Llandudno samples is of note, and probably reflects the minute rainfall catchment area of this part of the coast, with a corresponding lack of dilution of littoral sea-water. In contrast, numbers of *Cibicides lobatulus* are substantially greater than at Cape Town, probably indicating a more turbulent environment: a rocky shore rather than a beach. Again, a littoral to sublittoral environment is indicated by the foraminifera species present, though in such a wave-influenced shallow marine environment, considerable post-mortem transport of tests must have occurred. Macrofaunal debris is composed mainly of mollusc shell, some of which retains its life colours. In addition, barnacle plates, echinoid spines and sponge spicules occur.

TABLE 2

Distribution of foraminifera in studied samples from the latest Eemian–earliest Weichselian deposits of the Llandudno to Sandy Bay coast, Cape Peninsula.

	Sample number			Sp.	Species
SB-LL3	SB-LL2	SB-LL1	SB-1	no.	
			1	1	*Spiroplectammina* cf. *S. wrightii*
		1		2	*Quinqueloculina contorta*
3	2	2	5	3	*Quinqueloculina dunkerquiana*
1	1			4	*Quinqueloculina seminulum*
3	4	5	7	5	*Quinqueloculina* spp. (broken)
	2			6	*Siphonaperta* sp.
			1	7	*Lagena perlucida*
		1	3	8	*Lenticulina* spp.
	1			9	*Bulimina gibba*
	1		2	10	*Cassidulina laevigata*
			1	11	*Rosalina bradyi*
	1		1	12	*Rosalina* cf. *R. williamsoni*
			1	13	*Rosalina* sp.
	3	1	3	14	*Glabratella australensis*
17	55	27	71	15	*Cibicides lobatulus*
1	2	4	4	16	*Cibicides* spp. (broken)
1	1	3	2	17	*Cibicidoides* sp.
	1			18	*Hyalinea balthica*
	1			19	*Elphidium advenum*
	1		2	20	*Elphidium* sp. A
33	39	36	96	21	*Elphidium crispum* s.l.
	1	1		22	*Elphidium macellum* s.l.
	1			23	*Elphidium* sp. (broken)
21	56	24	149	24	*Pararotalia nipponica*
80	173	105	349		Total number of tests

Many of the species present are confined to the west-coast littoral at the present day, and indicate that, as with the Cape Town fauna, water temperatures were closely comparable to those experienced today along this coast. It seems likely that the very close similarity of the foraminifera species in the latest Eemian–earliest Weichselian of the south-western Cape and the Orange Shelf (McMillan 1987*b*) can be taken to indicate little difference in coastal sea-water temperatures between the two areas in the latest Pleistocene.

APPENDIX B

LATEST PLEISTOCENE FORAMINIFERA FROM BERG RIVER MOUTH

Further north along the west Cape coast, near the mouth of the Berg River, deposits of the same age (latest Eemian–earliest Weichselian, Unit III) as those of Cape Town city centre are preserved beneath the Holocene estuarine sediments. Recent dredging and channelling operations for a new marina at Port Owen, just inside the estuary mouth, have excavated muddy and shelly sands that have been used as fill over the adjacent area.

Two samples were collected in late 1986: one from a brown, clayey and lignitic sand, apparently *in situ*, near the base of a telephone pole next to the dredged marina channel (BR–2), and the other of muddy shelly sand dredged from the bed of the channel (BR–1). The localities of the samples are shown in Figure 19, and a list of the recovered foraminifera in Table 3. The two samples were from closely adjacent sites at 32°47′25″S 18°09′05″E.

TABLE 3

Distribution of foraminifera in two studied samples from the latest Eemian–earliest Weichselian deposits of the Berg River mouth, west Cape coast.

| Sample number BR-2	BR-1	Sp. no.	Species
	2	1	Bulimina elongata
	3	2	Bulimina gibba
	1	3	Trifarina angulosa
	1	4	Cassidulina laevigata
	1	5	Rosalina cf. R. globularis
	1	6	Glabratella australensis
8	6	7	Cibicides lobatulus
	1	8	Cibicides sp. (broken)
11	49	9	Elphidium advenum
1	21	10	Elphidium sp. A
18	3	11	Elphidium cf. E. alvarezianum
62	87	12	Elphidium crispum s.l.
10		13	Elphidium macellum s.l.
58	68	14	Ammonia japonica
1	1	15	Ammonia parkinsoniana s.l.
13	48	16	Pararotalia nipponica
182	293		Total number of tests
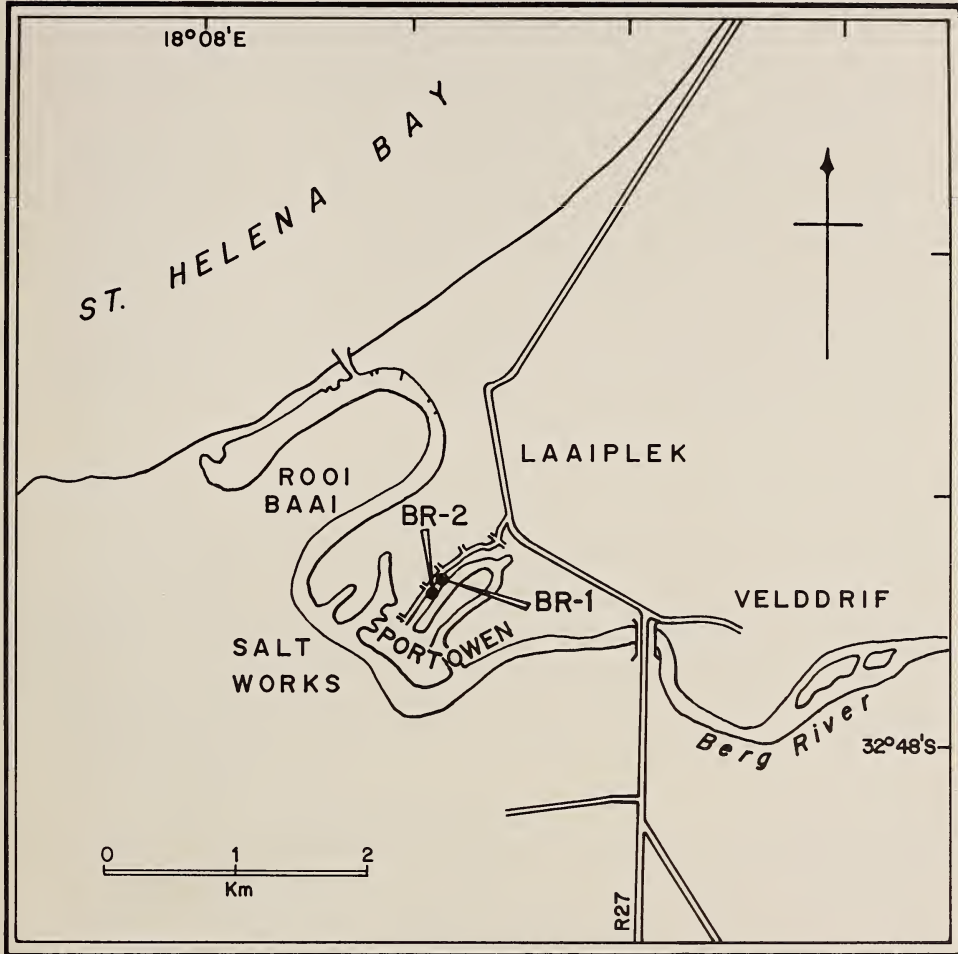
Fig. 19. Locality map of sampling sites at Berg River mouth, west Cape coast.

Both samples are rather gypsiferous, though this would seem to be a secondary feature derived from the overlying Holocene estuary. Present-day environments in the estuary are markedly hypersaline, and some areas are utilized for salt production. However, the foraminifera of the latest Pleistocene Unit III reveal a much more normal marine environment. *Cibicides lobatulus* (Walker & Jacob) occurs in fairly small numbers—as at Cape Town but unlike Llandudno—and is suggestive of a sandy beach environment rather than a rocky shore. *Ammonia japonica* (Hada) in such numbers clearly illustrates a good connection to the open sea, whereas the lack of *Ammonia parkinsoniana* (d'Orbigny) s.l. perhaps implies little fresh water entering the Berg estuary during the latest Eemian–earliest Weichselian. Very rare fragments of mollusc shell retain their

life colours, whereas all of the foraminifera tests are bleached. Occasional tests of *Ammonia parkinsoniana* s.l. with their natural brown colour are substantially better preserved than the rest of the assemblage, and are considered to be contamination from the Holocene estuarine deposits.

The brown sand contains much lignite and clay, and it yielded rather more corroded foraminifera tests than the channel sample. It seems likely that the clayey sand accumulated in a non-marine or estuarine mud-flat environment, as plant fragments, seeds and non-marine gastropods also occur. The marine foraminifera shells were probably carried off the adjacent beach and into the estuary by onshore winds. However, the absence of Holocene foraminifera in the clay clearly identifies it as having accumulated before the Holocene transgression. The abundance of *Elphidium crispum* (Fichtel & Moll) s.l. in both samples clearly shows these deposits to have been laid down at the time of the latest Eemian–earliest Weichselian regression.

APPENDIX C

LATEST PLEISTOCENE FORAMINIFERA OF HOEDJIESPUNT PENINSULA, SALDANHA

Although the main body of the white, shelly and sandy limestones that cap the Palaeozoic and older rocks of the Hoedjiespunt Peninsula are the most obvious latest Cainozoic deposits of this region, there nevertheless are small residues of an even later unit. Foraminifera from shelly parts of the main limestones (the Varswater Formation, and including the 'Saldanha Formation')

TABLE 4

Foraminifera species of one studied sample from the latest Eemian–earliest Weichselian sands of Hoedjiespunt Peninsula, Saldanha, west Cape coast.

Sample no. H-1	Sp. no.	Species
3	1	*Quinqueloculina dunkerquiana*
2	2	*Quinqueloculina seminulum*
11	3	*Quinqueloculina* spp. (broken)
1	4	*Siphonaperta* sp.
1	5	*Cassidulina laevigata*
24	6	*Glabratella australensis*
9	7	*Glabratella australensis* (reworked)
5	8	*Cibicides lobatulus*
12	9	*Cibicidoides* sp.
4	10	*Elphidium advenum*
3	11	*Elphidium crispum* s.l.
6	12	*Elphidium* sp. (reworked)
1	13	*?Haynesina* sp.
3	14	*Ammonia* spp. (reworked)
112	15	*Pararotalia nipponica*
21	16	*Pararotalia nipponica* (reworked)
238		Total number of tests

indicate a later Early Pleistocene age (see p. 132), regarded as equivalent in age to Unit IIA of the 'Bredasdorp Formation'.

However, bleached white, unconsolidated, shelly sands were recognized by Mr V. H. Valicenti about 8 m above high tide mark, below the Control Tower, on the north side of the Hoedjiespunt Peninsula, unconformably overlying the Varswater Formation limestones. Though severely affected by rainwash down-slope, and rather obscured by small plants and humus, as well as being contaminated with weathered debris from the adjacent limestones, one relatively clean sample was obtained. The locality is at 33°01′36″S 17°57′44″E, on Figure 20, and the foraminifera assemblage is listed in Table 4.

Despite the apparent cleanness of the sample, reworked foraminifera from the Varswater Formation do occur, but they can be easily identified by being cemented, creamy in colour and well preserved. *In situ* tests, in contrast, are
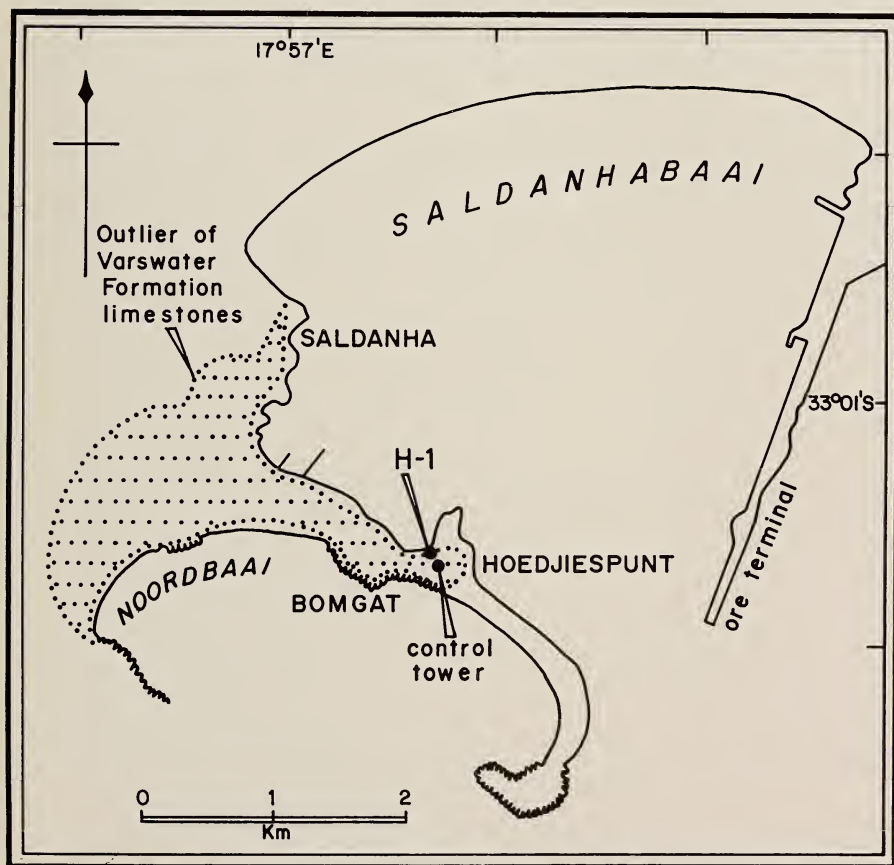

Fig. 20.   Locality map of the sampling site H–1 at Hoedjiespunt, Saldanha, west Cape coast.

bleached white, rather damaged, often displaying borings, poorly preserved, and often appear rather 'leached'.

Again, the age of the shelly sands is regarded as being latest Eemian–earliest Weichselian, based on the presence of *Elphidium crispum* (Linné) s.l. The absence of *Ammonia parkinsoniana* (d'Orbigny) s.l. would seem to duplicate the situation along the Llandudno–Sandy Bay coast, with little coastal dilution of seawater. As with the previous deposits studied, the mollusc shell often retains its life colours, but unlike elsewhere, tests of foraminifera are relatively rare.